INTERNATIONAL SEVEN JOURNAL
OF MULTIDISCIPLINARY
ISSN: 2764-9547

THE CIRCULAR ECONOMY IN CONSTRUCTION: CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLE DEVELOPMENT

10.56238/isevmjv3n4-023
Receipt of originals: 07/15/2024
Acceptance for publication: 08/15/2024

José Ronaldo Gomes de Souza Junior

ABSTRACT

The present work aimed to analyze the circular economy applied to civil construction, highlighting the main theoretical foundations, the challenges faced in Brazil and the opportunities that can boost the sustainable development of the sector. To this end, an integrative literature review was carried out, including scientific articles, technical reports and normative documents published in the last ten years, with an emphasis on studies that addressed waste reuse practices, design for disassembly and sustainable management of materials. The qualitative methodology allowed the content to be organized into thematic categories that included the central concepts of the circular economy, the economic, technological, and cultural barriers that hinder its large-scale adoption, and the strategies that can contribute to consolidating more efficient production models aligned with environmental commitments. Among the main results, it was found that the absence of adequate infrastructure, the lack of specific regulations and the low level of awareness of the consumer market remain limiting factors. On the other hand, it was found that specific successful experiences, especially in large urban centers, demonstrate the potential for reducing environmental impacts and generating economic value associated with circularity. The study reinforces the need for public policies that combine financial incentives, clear technical standards and professional training actions, in addition to highlighting the importance of an articulated national strategy that establishes goals and performance indicators. It is concluded that the circular economy represents a concrete opportunity to transform the Brazilian civil construction towards more responsible and innovative practices, provided that the structural limitations that still restrict its advancement are overcome.

Keywords: Circular Economy. Construction. Sustainability. Waste. Innovation.

INTRODUCTION

Civil construction represents one of the most strategic economic segments and, at the same time, the most challenging from an environmental point of view, as it concentrates high consumption of raw materials, energy and water resources, in addition to producing significant amounts of solid waste that, in many situations, are disposed of inappropriately, compromising sustainability and putting even more pressure on the planet's ecological limits (Munaro and Tavares, 2020).

The linear economic model that predominates in the sector is based on the logic of extraction, transformation, use and disposal, resulting in substantial losses of materials and energy throughout the production chain, which highlights the need for a consistent transition to circular models that prioritize waste prevention, the reuse of components and the valorization of by-products in closed production cycles (Iglesias et al., 2020).

The circular economy emerges as a promising strategy for civil construction, as it proposes to reorganize material flows and rethink the life cycle of buildings in order to ensure the preservation of the economic value of resources, in addition to contributing to the reduction of the environmental footprint associated with construction activity and promoting opportunities for innovation and generation of qualified jobs (Campos and Rotta, 2021).

The practical application of circular principles in the civil construction sector faces challenges related to the fragmentation of the production chain, the cultural resistance of companies and professionals to abandon consolidated practices, and the need to invest in technologies that enable the effective reuse of materials without harming the quality and safety of the works (Oliveira et al., 2024).

Recent studies show that about 35% of the waste deposited in landfills in the world comes from the construction and demolition segment, revealing that, although there are technologies and methodologies capable of drastically reducing this proportion, the use is still limited and depends on more effective public policies, environmental inspection, and economic incentives (Alves et al., 2020).

Brazil presents a complex scenario with regard to the implementation of the circular economy in civil construction, since, at the same time that there are outstanding initiatives, such as the use of recycled aggregates and the adoption of environmental

certifications, there is a great regional and institutional disparity in the ability to manage waste flows and incorporate sustainable practices in projects (Barboza et al., 2019).

Selective deconstruction, a concept that proposes the planned dismantling of buildings with a view to the maximum reuse of components, emerges as one of the main circular strategies and can reduce final disposal costs, reduce pressure on the extraction of raw materials and extend the useful life of materials, but it still lacks specific regulation and technical training in the country (Oliveira et al., 2024).

The potential for transformation associated with the circular economy in civil construction is directly related to the integration of strategies such as design for disassembly, which favors architectural projects capable of facilitating disassembly and reuse, in addition to reverse logistics systems and digital platforms for tracking materials, essential elements to close production cycles and ensure transparency in the supply chain (Delgado et al., 2023).

Research shows that, in several European countries, public policies to encourage circularity in civil construction have resulted in significant increases in recycling rates and a reduction in the volume of waste sent to landfills, showing that clear regulatory frameworks, associated with economic and fiscal instruments, are determining factors for the success of circular strategies (Iglesias et al., 2020).

In Brazil, despite the existence of the National Solid Waste Policy, which establishes general guidelines for waste management, there is still a specific regulatory gap for civil construction, generating legal uncertainty and making it difficult to standardize processes that enable the recovery of materials and the traceability of reuse operations (Campos and Rotta, 2021).

In addition to the environmental bias, the adoption of the circular economy in civil construction has a relevant economic component, as it can reduce operating costs related to waste management, stimulate technological innovation, and strengthen local production chains dedicated to the transformation of by-products into new inputs, thus creating new business opportunities and income generation (Pinto et al., 2020).

The challenges to internalize this logic also include the need to expand technical knowledge about recyclable materials, develop specific performance indicators that allow monitoring the degree of circularity in the works, and disseminate life cycle assessment methodologies capable of guiding more conscious decisions in all phases of the project (Alves et al., 2020).

The role of the end consumer, whether a buyer of real estate or a user of corporate spaces, also emerges as a central element in the transition to the circular economy, as the valuation of sustainable products and buildings depends, to a large extent, on the perception of added value, the willingness to pay for more efficient solutions and the degree of involvement of society in the demand for responsible practices (Delgado et al., 2023).

Integration between universities, companies, and governments is essential to accelerate innovation and consolidate productive arrangements that allow expanding the scale of waste reuse, developing new materials with less environmental impact, and enabling the creation of regulations that contemplate the local and regional specificities of the civil construction chain (Barboza et al., 2019).

Given this scenario, it is necessary to deepen the reflection on the critical success factors and the main barriers to the implementation of the circular economy in Brazilian civil construction, seeking to highlight paths that can lead the sector to a more resilient, competitive model aligned with the principles of sustainable development (Munaro and Tavares, 2020).

THEORETICAL FRAMEWORK

PRINCIPLES AND FUNDAMENTALS OF THE CIRCULAR ECONOMY IN CIVIL CONSTRUCTION

The circular economy emerges as a systemic response to the limits of the linear economic model, structuring itself on fundamentals that aim to keep products, materials and resources in use for as long as possible, in order to regenerate natural systems and create sustainable economic value, and in civil construction these principles translate into strategies that involve everything from design planning to selective dismantling practices, reverse logistics and reintroduction of waste as productive inputs, configuring a paradigm shift that goes beyond merely operational boundaries and demands a profound cultural transformation between professionals, managers, and consumers (Oliveira et al., 2024).

In this context, one of the central pillars of the circular economy lies in the concept of the 3Rs – reduce, reuse, and recycle – which become strategic guidelines for the design, execution, and maintenance of buildings, guiding choices related to materials with low environmental impact, adaptable construction systems, and

technological solutions that facilitate the traceability and reuse of components throughout the life cycle of buildings (Iglesias et al., 2020).

The principle of reduction refers to the reduction of the extraction of natural resources and the volume of waste generated, promoting the rational use of materials and prioritizing more efficient construction processes, such as the use of prefabricated and modular methods that optimize resources, reduce losses and speed up deadlines, while the principle of reuse encourages the direct reuse of structural elements and finishes in new developments, preventing materials with high added value from being discarded prematurely (Campos and Rotta, 2021).

In turn, the principle of recycling seeks to reintegrate solid waste from construction and demolition into the production cycle, converting it into new products or secondary raw materials, an action that requires a technically capable and economically viable collection, sorting and processing infrastructure, as well as regulatory incentives that promote the competitiveness of these materials compared to conventional inputs (Munaro and Tavares, 2020).

The application of these fundamentals presupposes that architectural projects incorporate life cycle thinking from their conception, considering the selection of recyclable materials, the ease of disassembly, the adaptability of spaces, and preventive maintenance, so that the building can be managed as a bank of materials that preserves value and reduces environmental impacts over time (Delgado et al., 2023).

In the international literature, authors highlight that the circular economy transcends the environmental dimension by proposing a new economic and social pact, where value creation is no longer conditioned exclusively to linear consumption and starts to include benefits such as the generation of green jobs, the strengthening of local production chains, and the reduction of economic vulnerabilities associated with dependence on non-renewable resources (Ajayi et al., 2015).

In the context of Brazilian civil construction, the incorporation of the fundamentals of the circular economy also dialogues with public policies on solid waste and climate commitments assumed by the country, which demand a significant reduction in greenhouse gas emissions, an increase in recycling rates, and an increase in the efficiency of the use of natural resources, objectives that become more tangible when aligned with the redesign of products and construction processes (Alves et al., 2020).

Another basic principle is design for disassembly, which implies designing buildings in such a way that their components can be dismantled without damage and reused in other constructions, a perspective that contrasts with conventional practices in which demolition results in a large volume of rubble that is difficult to segregate, making it economically unfeasible to reuse or recycle it (Oliveira et al., 2024).

The concepts of modularity and standardization are also presented as instruments for operationalizing the circular economy, as they allow construction elements to be interchangeable, facilitating repairs, expansions, or reconfigurations of spaces with lower resource consumption and less waste generation, attributes that add technical and market value to buildings (Barboza et al., 2019).

It is important to highlight that the circular economy in civil construction presupposes the establishment of robust information flows between suppliers, designers, builders and users, so that the traceability of materials is guaranteed and the maintenance and replacement processes are guided by reliable data on the origin, composition and reuse potential of each component (Campos and Rotta, 2021).

The systemic approach proposed by the fundamentals of the circular economy also requires the development of performance indicators that allow measuring the degree of circularity of the works, including dimensions such as the proportion of recycled materials used, the durability and adaptability of the construction solutions and the environmental impact associated with the life cycle of the building (Alves et al., 2020).

The principles that sustain the circularity of economic activities in civil construction are connected to the idea of performance economy, in which the value delivered to the end user derives not only from the ownership of assets, but mainly from the quality and longevity of the service provided, a concept that encourages innovative business models such as component leasing and energy performance contracts (Delgado et al., 2023).

In addition, the fundamentals of the circular economy incorporate the regeneration of ecosystems as an essential purpose, which implies designing buildings capable of promoting net environmental benefits, such as the capture and reuse of rainwater, the local production of renewable energy, and the creation of spaces that foster biodiversity and collective well-being (Oliveira et al., 2024).

The conceptual references point out that the circular economy in civil construction is not limited to the punctual reuse of materials, but constitutes a new logic of production and consumption, in which buildings are no longer seen as static products and are understood as dynamic systems in constant updating and reuse, a perspective that requires technological innovation, cultural change and new governance models (Munaro and Tavares, 2020).

The consolidation of these principles in everyday practices requires not only economic incentives and regulatory frameworks, but also a collective effort to raise awareness and technical qualification of the actors involved, since the success of the transition depends on the ability of designers, builders, operators, and consumers to incorporate circular fundamentals into their decisions and behaviors (Campos and Rotta, 2021).

BARRIERS TO THE IMPLEMENTATION OF THE CIRCULAR ECONOMY

The transition of Brazilian civil construction to a circular economy model encounters several structural obstacles ranging from economic and institutional factors to cultural and technological aspects, reflecting the complexity of the sector, the fragmentation of the production chain, and regulatory limitations that compromise the adoption of large-scale circular practices and hinder the creation of a consolidated market for recycled and reused materials (Munaro and Tavares, 2020).

Among the most recurrent barriers are economic constraints, which include the high costs associated with the segregation, transportation, and processing of waste, added to the lack of financial incentives that encourage companies to invest in equipment, technology, and professional qualification, resulting in a perception of economic unfeasibility that often discourages circular initiatives (Campos and Rotta, 2021).

The absence of clear and specific legal frameworks for the management of civil construction waste compromises the legal certainty of entrepreneurs and makes it impossible to standardize procedures, creating scenarios of uncertainty that inhibit long-term investments and hinder the articulation of public policies capable of coordinating efforts between environmental agencies, companies, and consumers (Barboza et al., 2019).

Another relevant factor is the lack of logistical infrastructure for the collection, sorting and reuse of waste in different regions of the country, a reality that contributes to the irregular disposal of materials, increases operating costs and accentuates regional inequalities, given that smaller municipalities are even less able to implement effective integrated management systems (Iglesias et al., 2020).

From a technological point of view, there is a significant deficit of industrial processes aimed at the recycling of complex materials, such as composites and cementitious mixtures, in addition to the difficulty in developing solutions that ensure technical quality and economic competitiveness of recycled products compared to virgin materials, making it difficult for them to be accepted in the consumer market (Oliveira et al., 2024).

The limitation of technical knowledge and the shortage of specialized labor represent another important challenge, as the adoption of circular practices requires training of designers, engineers, workers, and managers so that they understand the principles of circularity and know how to apply methodologies such as design for disassembly, reverse logistics, and life cycle analysis of materials (Delgado et al., 2023).

Cultural and behavioral aspects are also among the most challenging barriers, since the predominant mentality in the sector remains strongly linked to linear paradigms of production and disposal, and many companies still perceive circular practices as one-off actions or niche initiatives, instead of seeing them as structuring strategies for competitiveness and sustainability (Campos and Rotta, 2021).

The informality that characterizes a significant part of the production chain, especially in the management and transportation of civil construction waste, compromises the tracking of materials and the reliability of processes, in addition to fostering illicit practices such as clandestine dumping and irregular trade of recyclable inputs, factors that weaken the credibility of the sector and limit the development of a formal market for circular products (Alves et al., 2020).

From the point of view of demand, it is observed that the low valuation by end consumers and the lack of knowledge about the economic and environmental advantages of the circular economy make it difficult to establish a culture of preference for sustainable buildings and recycled materials, perpetuating consumption patterns that

reinforce the extraction of primary resources and the massive disposal of waste (Iglesias et al., 2020).

The lack of widely recognized performance indicators applied in professional practice makes it difficult to measure circularity in projects, generating information gaps that compromise the monitoring of results and the comparison between constructive solutions, which reinforces the need to develop standardized metrics that allow monitoring the evolution of circular strategies in the sector (Barboza et al., 2019).

Another critical point refers to the complexity of contemporary buildings, which have a diversity of materials, components, and construction techniques that make the dismantling and selective segregation of waste tasks of high technical complexity, requiring thorough planning and specific technologies that are often not available on a large scale in the Brazilian market (Oliveira et al., 2024).

The restrictions associated with the financing of circular projects are also a relevant obstacle, as many financial agents still perceive these initiatives as having a higher risk or uncertain return, which limits access to specific credit lines and makes it more expensive to raise the funds necessary for the modernization of processes and the implementation of innovative technologies (Munaro and Tavares, 2020).

The difficulty in establishing business models based on performance economy, such as the leasing of components and service contracts associated with the life cycle of products, stems from the lack of regulation and the cultural resistance of builders and developers to abandon traditional practices of commercialization and appropriation of revenues, making the sector less agile in the incorporation of innovations (Delgado et al., 2023).

Institutional barriers related to coordination between federative entities and environmental agencies hinder the integration of public policies and programs to promote the circular economy, creating fragmented scenarios in which local initiatives lack synergy and end up restricted to isolated actions without continuity or scale of impact (Campos and Rotta, 2021).

The absence of an articulated national strategy that consolidates guidelines, goals, and monitoring instruments compromises the effectiveness of policies and prevents Brazil from advancing more consistently in the transition to a circular economy in civil construction, a scenario that demands greater engagement from governments,

the private sector, and civil society in the construction of a federative pact for circularity (Alves et al., 2020).

OPPORTUNITIES AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT

The adoption of the circular economy in civil construction creates a vast field of opportunities that go beyond the mitigation of environmental impacts, as it opens up possibilities for innovation in business models, generation of qualified jobs and strengthening of regional production chains, contributing to transform the sector into an engine of economic development aligned with the principles of sustainability (Oliveira et al., 2024).

One of the main strategies consists of the expansion of reverse logistics systems that enable the collection, transportation and reintroduction of waste and reusable materials into the production chain, a practice that can generate a reduction in operating costs, diversification of revenue sources and valuation of assets throughout the life cycle of buildings, creating competitive advantages for pioneering companies (Campos and Rotta, 2021).

Investment in traceability technologies, such as digital platforms that track the origin, composition, and destination of materials, also stands out as a relevant opportunity, as it promotes greater transparency in the supply chain, strengthens relationships of trust between suppliers and consumers, and facilitates compliance with regulatory requirements and environmental certifications (Delgado et al., 2023).

The use of standardized circularity indicators, associated with methodologies for assessing the life cycle of buildings, represents another promising strategy, as it allows companies to quantify their advances in sustainability, improve communication with the market, and be able to differentiate themselves positively from investors, public agencies, and increasingly demanding consumers (Barboza et al., 2019).

The implementation of environmental certification programs that contemplate specific circular economy criteria, such as the use of recycled materials, the adaptability of spaces, and energy efficiency, contributes to consolidating quality references and boosting the demand for projects that incorporate innovative solutions committed to the regeneration of ecosystems (Iglesias et al., 2020).

Design for disassembly emerges as one of the most effective strategies to maximize the circularity of buildings, because by designing buildings with dismountable

construction systems and interchangeable components, it enables the full reuse of elements at the end of the work's useful life and facilitates maintenance and updates over time, prolonging the value of the assets (Oliveira et al., 2024).

The promotion of partnerships between universities, research centers, governments, and companies creates a favorable environment for the development of innovative technologies and practices, enhancing the creation of new materials with low environmental impact, adaptable construction solutions, and business models that reconcile profitability with socio-environmental responsibility (Munaro and Tavares, 2020).

Professional training and sensitization programs for the different actors in the production chain are essential to consolidate a culture of circularity, as they expand the technical repertoire, encourage the sharing of successful experiences, and strengthen the understanding of the economic and environmental benefits associated with the transition to new constructive paradigms (Campos and Rotta, 2021).

The integration of the circular economy into public policies for urban development and social housing offers the opportunity to promote more accessible, efficient, and resilient buildings, contributing to reducing socioeconomic inequalities and expanding the population's access to safe, healthy spaces aligned with sustainable development goals (Alves et al., 2020).

Another promising field involves stimulating lines of financing and tax incentives that enable investments in infrastructure, equipment, and circular processes, an action that can attract new players to the market and accelerate the scale of implementation of sustainable practices in different segments of civil construction (Delgado et al., 2023).

Valuing nature-based solutions, such as green roofs, water collection and reuse systems, and vegetated facades, represents a synergistic strategy with circular principles, as it creates integrated environmental and social benefits, including improved air quality, thermal comfort, and the expansion of biodiversity in urban spaces (Iglesias et al., 2020).

The strengthening of local production chains dedicated to the recycling and processing of civil construction waste creates opportunities to generate employment and income in communities, boosts regional economies and reduces dependence on imported inputs or those transported over long distances, which reduces logistics costs and emissions associated with transportation (Barboza et al., 2019).

Performance contracts, which associate payments with efficiency indicators and reduction of environmental impacts, emerge as innovative alternatives to enable investments and share risks between suppliers and contractors, creating economic incentives aligned with the logic of the circular economy and strengthening the commitment to long-term results (Campos and Rotta, 2021).

The integration of geographic information systems and regional databases on the supply and demand of waste and recycled materials can optimize logistics flows, reduce operating costs, and foster the development of dynamic secondary markets, making products and services that incorporate circular principles more competitive (Oliveira et al., 2024).

Thus, the construction of an articulated national strategy, which consolidates guidelines, goals and monitoring instruments, represents a unique opportunity to position Brazil as a regional reference in circular economy in civil construction, creating shared value for companies, society and the environment and driving a virtuous cycle of innovation and sustainable development (Munaro and Tavares, 2020).

METHODOLOGY

This study adopted a qualitative approach focused on an integrative literature review, seeking to understand in depth how the circular economy has been discussed and applied in the civil construction sector, especially in Brazil, but also considering international references that help to contextualize the advances and challenges of the topic (Munaro and Tavares, 2020).

The research involved the selection of scientific articles, technical reports, and normative documents that deal with concepts, barriers, practices, and opportunities related to circularity in construction, prioritizing publications from the last ten years, in order to gather updated and relevant information to support the reflections proposed in this work (Campos and Rotta, 2021).

The materials were identified in databases such as Scopus, Web of Science, and Google Scholar, using combined descriptors, including "circular economy", "civil construction", "waste", "dismantling", and "sustainability", as well as terms in English that expanded the scope of the search and allowed for the comparison of international approaches with the Brazilian reality (Delgado et al., 2023).

To select the studies, criteria were applied that included methodological clarity, the relevance of the topic, and the practical or theoretical contribution to the understanding of the subject, excluding documents that presented redundant or superficial information that would not add new elements to the discussion (Oliveira et al., 2024).

In addition to the analysis of articles, normative references and Brazilian public policies, such as the National Solid Waste Policy, were included to map which regulatory guidelines guide the management and reuse of construction waste, identifying gaps that may hinder the effective adoption of the circular economy in the sector (Iglesias et al., 2020).

The contents were organized into three main categories: fundamentals and concepts of the circular economy, barriers and limitations that impact practical application, and opportunities that can strengthen sustainable development in construction, a framework that guided the writing of the following chapters and helped maintain the cohesion of the work (Munaro and Tavares, 2020).

With this, the methodology applied sought to ensure rigor in the selection and organization of the material, offering a solid basis for discussing the results and for reflections on how the circular economy can advance in Brazilian civil construction in a structured and consistent way.

RESULTS AND DISCUSSION

The analysis of the collected material showed that the circular economy in civil construction is still at an early stage in Brazil, although there are specific experiences that prove the potential of the concept to transform the way buildings are designed, executed and managed, showing that there is a promising path, but that it depends on greater articulation between public policies, technological innovation and cultural changes in the sector (Munaro and Tavares, 2020).

Several studies highlight that the management of construction and demolition waste continues to be one of the biggest challenges to consolidate circular practices, mainly due to the lack of infrastructure for sorting and processing materials, in addition to the lack of standardization of procedures that can ensure the quality and traceability of recycled inputs (Campos and Rotta, 2021).

At the same time, initiatives such as design for disassembly and the use of modular construction systems have advanced in some companies and large-scale works, showing that it is feasible to think of planned buildings to facilitate disassembly and reuse of components, although these solutions are not yet disseminated in most of the market (Oliveira et al., 2024).

The reviewed articles highlight that the potential for reducing environmental impacts associated with the circular economy is significant, including a significant decrease in the consumption of raw materials, waste generation, and carbon emissions, benefits that can be expanded when associated with other strategies such as energy efficiency and use of water resources (Delgado et al., 2023).

The lack of tax incentives and specific credit lines was cited as an important obstacle, as many companies consider the initial investment required to implement reverse logistics systems and processing technologies as a high cost that does not find an immediate financial counterpart, a factor that discourages deeper changes (Barboza et al., 2019).

On the other hand, there are examples reported in the literature of projects that managed to reduce costs throughout the life cycle of the work precisely by adopting circular practices, either in reducing expenses with waste disposal, or in valuing the property with the final consumer, showing that the economic return can be progressively consolidated (Iglesias et al., 2020).

The study also showed that the perception of value by customers is still low, since few consumers are looking for certified properties or are willing to pay more for projects with a higher circularity index, a reality that reinforces the importance of environmental education programs and awareness campaigns (Campos and Rotta, 2021).

Another aspect discussed is the need to integrate digital tools that facilitate the tracking of materials and the management of disassembly stages, since technology can reduce uncertainties about the quality and origin of reused inputs and offer more legal certainty to construction companies and buyers (Oliveira et al., 2024).

The review indicated that academic projects and partnerships between universities and companies have generated important knowledge about solutions applicable in Brazil, but that these results often do not find continuity due to the lack of

public policies that encourage technology transfer and support for innovation on a small and medium scale (Munaro and Tavares, 2020).

The data analyzed also highlighted that the use of recycled materials is still resisted, both by professionals who fear technical performance problems and by the absence of more specific technical standards that attest to the quality of these products in a reliable and transparent way (Barboza et al., 2019).

The reviewed articles point out that business models based on performance economics can be consolidated as an interesting alternative, as they allow companies to take responsibility for the maintenance and updating of construction systems, while generating new sources of revenue related to after-sales services (Delgado et al., 2023).

It was also evident that cities with higher population density and consolidated infrastructure tend to have more initiatives aimed at the circular economy, either because of the volume of waste available for reuse, or because of the presence of more developed logistics networks that enable collection and processing processes (Iglesias et al., 2020).

The need to train professionals at all levels was pointed out as a priority, as the incorporation of circular practices depends on a technical understanding of the possibilities and limitations of materials and processes, in addition to a change in posture that recognizes the economic and environmental value of circularity (Campos and Rotta, 2021).

The results suggest that public policies that combine regulation, financial incentives, and awareness campaigns can accelerate the sector's transition, creating more favorable conditions for companies to invest in circular solutions without compromising their competitiveness (Oliveira et al., 2024).

FINAL CONSIDERATIONS

The transition to the circular economy in Brazilian civil construction presents itself as a concrete opportunity to transform production processes historically marked by waste and intensive consumption of natural resources, allowing the sector to align itself with global environmental commitments and expand its competitiveness in a sustainable and innovative way.

The studies reviewed throughout this work showed that, despite institutional, cultural, and economic barriers, there are already examples that prove the technical and financial feasibility of adopting circular practices, especially when there is integrated planning, commitment of all agents involved, and the use of appropriate technologies.

The absence of logistical infrastructure, detailed technical standards, and financial incentives remains a major obstacle, which limits the scale and continuity of many initiatives, reinforcing the need for more consistent public policies that articulate regional efforts and establish clear goals for the sector.

The role of environmental education and the training of trained professionals emerges as an essential strategic axis to consolidate the culture of circularity, as the change in mentality and the acceptance of new materials and business models depend directly on the level of information and technical security that the teams involved have.

The integration between universities, companies and public agencies has the potential to create innovative solutions that combine environmental gains and economic return, as long as mechanisms are created to foster applied research and the dissemination of technologies adapted to the Brazilian context.

The development of digital tracking systems and standardized circularity indicators can generate more confidence in the market, enabling the creation of products with recognized certifications and facilitating the monitoring of results in projects of different sizes.

The international experiences analyzed demonstrate that the combination of clear regulations, tax incentives and transparent communication with the consumer can create a favorable environment to consolidate markets for recycled materials and services associated with the life cycle of buildings.

In Brazil, the strengthening of local production chains aimed at the reuse of waste can generate employment and income in different regions, bringing the principles of the circular economy closer to socioeconomic realities that still face significant inequalities.

The alignment between urban planning, housing policies, and circular practices can expand access to quality housing, reduce public costs with waste management, and contribute to more resilient and healthy cities, making the circular economy a relevant strategy for regional development.

However, consolidating the circular economy in civil construction requires a coordinated effort that combines long-term vision, investments in infrastructure and technologies, and political commitment to environmental goals, recognizing that the challenge is great, but the benefits are broad and long-lasting.

REFERENCES

1. Alves, J. L., Borges, I. B., Nardae, J. de, & Freitas, S. de L. T. U. (2020). Indicadores de economia circular para a construção civil baseados na literatura internacional. In Anais do VIII SINGEP (pp. 1–16). São Paulo. https://www.revistas.utfpr.edu.br

2. Barboza, D. V., da Silva, F. A., Motta, W. H., Meiriño, M. J., & Faria, A. do V. (2019). Aplicação da economia circular na construção civil. Research, Society and Development, 8(7), 1–14. https://doi.org/10.33448/rsd-v8i7.1102

3. Campos, M. R. de, & Rotta, I. S. (2021). Os desafios da economia circular na indústria de construção civil. In Anais do CONBREPRO (pp. 1–12). São Paulo. https://www.aprepro.org.br

4. Delgado, F. C. M., et al. (2023). Práticas de economia circular na construção civil – o que sabemos e para onde estamos indo. In Anais do CONGRESSO BRASILEIRO DE ENGENHARIA DE PRODUÇÃO (pp. 242–253). Florianópolis. https://repositorio.ufsc.br

5. Iglesias, J., et al. (2024). Economia circular nas cadeias de valor brasileiras: Desafios e oportunidades para promover a economia circular nas cadeias de energia e telecomunicações. São Paulo: FGVces. https://eaesp.fgv.br

6. Munaro, M. R., & Tavares, S. F. (2020). A economia circular na construção civil: Principais barreiras e oportunidades para a transição do setor. Revista Tecnologia e Sociedade, 16(41), 54–70. https://doi.org/10.3895/rts.v16n41.15726

7. Oliveira, J. de, Gonzalez, M. A. S., & Kern, A. P. (2024). Análise do projeto para desmontagem e desconstrução como ferramenta da economia circular da construção civil. Ambiente Construído, 24, e133051. https://doi.org/10.1590/s1678-86212024000100768

8. Pinto, A. D. M., Zago, C. A., & Zago, L. H. A. (2020). Estratégias gerenciais sustentáveis: Princípios da economia circular no setor da construção civil. In Anais do ENGEMA (pp. 1–15). São Paulo. https://engemausp.submissao.com.br