

^{1,2}Elena MARICA, ²Maria POPA

CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT: EFFICIENT VALORIZATION SOLUTIONS IN THE CONTEXT OF THE CIRCULAR ECONOMY

¹ “Lucian Blaga” University of Sibiu, Doctoral School of Engineering and Mathematical Sciences, Sibiu, ROMANIA² “1 Decembrie 1918” University of Alba Iulia, Department of Cadastre, Civil Engineering and Environmental Engineering, Alba Iulia, ROMANIA

Abstract: The construction industry generates significant amounts of waste, representing one of the major challenges for environmental protection and the efficient use of resources. Proper management of this waste is essential for reducing environmental impacts and promoting the principles of the circular economy. The aim of this paper is to highlight several efficient approaches for the valorization of construction and demolition waste by identifying solutions that enable the reuse, recycling, and recovery of materials resulting from these activities. The study analyzes the main categories of waste generated, as well as the possibilities for their reintegration into the economic cycle. The results indicate that the implementation of effective waste valorization practices contributes to reducing the consumption of natural resources, minimizing the quantities of waste disposed of in landfills, and enhancing sustainability within the construction sector. Therefore, the valorization of construction and demolition waste represents an important component of waste management and a key factor in the transition toward a circular economy.

Keywords: construction and demolition waste (CDW), waste management, material recovery, recycling, reuse, circular economy, sustainability

INTRODUCTION

The construction industry is one of the most important economic sectors, playing a crucial role in the development of infrastructure and the built environment [1]. At the same time, this sector generates significant amounts of waste resulting from construction, renovation, rehabilitation, and demolition activities [2]. Within the European Union, construction and demolition waste (CDW) represents the largest waste stream, accounting for more than 800 million tonnes annually, corresponding to approximately 32% of the total waste generated [3].

Construction and demolition waste includes materials such as concrete, bricks, ceramic materials, wood, metals, glass, and asphalt materials, many of which have a high potential for reuse and recycling [2]. According to previous studies [3], this type of waste accounts for more than one-third of the total waste generated in the European Union, highlighting the importance of implementing efficient management and valorization systems.

Waste management encompasses all activities and measures aimed at preventing waste generation, as well as the collection, transportation, sorting, reuse, recycling, recovery, and disposal of waste in a manner that ensures the protection of both human health and the environment. In the construction and demolition sector, effective waste management is essential for reducing negative environmental impacts and improving resource efficiency [4]. The implementation of appropriate waste management practices enables the recovery

of substantial quantities of reusable and recyclable materials, contributing to a reduction in raw material consumption and the amount of waste sent to landfill [5-7]. Furthermore, the implementation of modern waste management systems can generate economic benefits by reducing waste disposal costs and promoting the valorization of recovered materials [8,9].

According to the Waste Framework Directive (2008/98/EC), waste management should be carried out in accordance with the waste hierarchy, which prioritizes waste prevention, followed by reuse, recycling, and other recovery operations, while disposal is considered the least preferred option. In the case of construction and demolition waste, European legislation has established ambitious targets regarding the preparation for reuse, recycling, and recovery of materials generated within this waste stream.

In recent years, the concept of the circular economy has become a central element of European policies aimed at promoting the efficient use of resources and reducing environmental impacts. Unlike the traditional linear economic model based on the principle of “take-make-consume-dispose”, the circular economy seeks to keep materials and resources in use for as long as possible through reuse, repair, recycling, and recovery. In this context, construction and demolition waste (CDW) management plays a crucial role, as it enables the transformation of waste materials into secondary resources that can be reintegrated into new production processes. The application of circular economy principles within

the construction sector contributes to reducing raw material consumption, minimizing waste disposal, and enhancing the sustainability of the entire building life cycle [5,7,10,11].

The aim of this paper is to highlight several efficient approaches for the valorization of construction and demolition waste by analyzing the main methods of material reuse, recycling, and recovery. Furthermore, the study seeks to emphasize the environmental and economic benefits associated with these practices, as well as their role in supporting the transition toward a circular economy and a more sustainable construction sector. The paper contributes to the existing literature by providing a structured overview of efficient CDW valorization pathways and by synthesizing key technological and environmental considerations relevant to their practical implementation.

Despite significant progress in CDW management practices, the effective large-scale implementation of circular economy strategies remains uneven across regions, mainly due to technical, economic, and regulatory barriers.

MATERIALS AND METHODS USED

The present study is based on a review of the scientific literature, national and European legislative documents, and relevant studies concerning the management and valorization of waste generated by construction and demolition activities. The research focused on the main waste streams produced within this sector, including concrete, bricks, ceramic materials, wood, metals, and asphalt materials. The methodology employed consisted of a comparative assessment of various waste management and valorization approaches, with particular emphasis on material reuse, recycling, and recovery. The analysis aimed to identify the most effective valorization solutions by considering environmental impacts, resource-use efficiency, and their contribution to the sustainable development of the construction sector.

Furthermore, construction and demolition waste (CDW) management was examined in accordance with the principles of the waste hierarchy, which prioritizes waste prevention, followed by reuse and recycling, before final disposal. The application of this approach facilitates the reduction of waste quantities destined for landfill and promotes the reintegration of recovered materials into the economic cycle, in line with the principles of the circular economy.

RESULTS AND DISCUSSION

The analysis of the reviewed literature highlights that construction and demolition waste (CDW) management represents an essential component of the transition toward a more sustainable construction industry. Waste generated from

construction, rehabilitation, and demolition activities includes materials with a high potential for valorization, such as concrete, bricks, ceramic materials, metals, wood, asphalt, and other mineral components. In this context, the scientific literature indicates that the reuse and recycling of these materials can reduce pressure on natural resources, limit the quantities of waste disposed of in landfills, and contribute to the implementation of circular economy principles [5-7,20]. Among the identified valorization pathways, recycled aggregate production represents the most extensively studied and industrially relevant solution.

European best practices for construction and demolition waste management promote waste prevention, source separation, selective collection, recycling of mineral materials, and the development of markets for recycled products [5]. These measures are essential because the quality of recycled materials largely depends on collection and sorting procedures. Mixed or contaminated waste streams are more difficult to recover and may result in recycled products with reduced performance [5,7].

The analyzed results indicate that construction and demolition waste management is one of the key components of the circular economy within the construction sector. Through selective collection, recycling, and reuse of materials generated from demolition activities, it is possible to significantly reduce the consumption of natural resources and the demand for raw materials used in the production of new construction materials. The literature shows that recycled aggregates, reclaimed asphalt materials, and other recovered materials can partially replace conventional resources without compromising the technical performance of the final products [11-14]. Therefore, effective waste management not only contributes to environmental protection but also enhances economic efficiency and supports the development of a more resilient and sustainable construction sector [5,9-10].

One of the most extensively investigated valorization pathways involves the use of recycled aggregates obtained from demolished concrete in the production of new concrete mixtures. Studies have shown that recycled aggregates can partially replace natural aggregates; however, the performance of the resulting concrete depends on several factors, including the quality of the parent material, the degree of contamination, the crushing method, water absorption, and the replacement ratio employed [12,15-17]. In general, recycled aggregates exhibit higher porosity and greater water absorption than natural aggregates due to the presence of residual mortar adhered to the surface of the particles [14,18-19].

Results reported in the literature indicate that recycled aggregate concrete can achieve satisfactory mechanical properties when the mix design is properly optimized. Limbachiya et al. demonstrated that the use of moderate proportions of recycled aggregates can enable the production of high-strength concrete without significant reductions in mechanical performance [16]. Nevertheless, other studies have highlighted that the complete replacement of natural aggregates may lead to reductions in compressive strength and splitting tensile strength, depending on the quality of the recycled aggregates and the concrete mix composition [15-17].

The durability of recycled aggregate concrete is another important aspect affecting its practical application in construction. Thomas et al. investigated the behavior of recycled aggregate concrete in terms of its physical, mechanical, and durability properties, emphasizing the influence of aggregate characteristics on long-term performance [13]. Furthermore, studies focusing on the moisture condition of recycled aggregates indicate that moisture content significantly affects workability, the effective water-to-cement ratio, and the strength development of concrete [18], [22]. For this reason, proper water control and the pre-saturation of recycled aggregates may represent effective strategies for producing recycled aggregate concrete with more stable and predictable properties [18-19].

An important research direction concerns the use of recycled fine aggregates in concrete production. Nedeljkovic et al. reported that recycled fine aggregates are more difficult to control than coarse recycled aggregates due to their higher content of fine particles, increased water absorption, and greater influence on concrete workability [14]. Nevertheless, through appropriate material selection and mix optimization, recycled fine aggregates can be successfully incorporated into certain applications, contributing to a reduction in the consumption of natural aggregate resources [11,14].

Figures 1 and 2 present a comparison between recycled aggregates used in construction and the behavior of fresh concrete containing them, highlighting the material characteristics and their effect on the mixture in its fresh state.

The images 1 and 2 emphasize the morphological differences between natural and recycled aggregates, as well as the influence of recycled content on the workability and consistency of fresh concrete mixtures.

In addition to conventional concrete applications, the literature highlights innovative approaches for waste valorization. Kong et al. investigated the use of recycled aggregates combined with oyster shell waste to produce eco-friendly porous concrete

intended for artificial reef applications [20]. Such approaches demonstrate that construction and demolition waste can be incorporated into materials with specialized functions rather than being limited to traditional construction products. Similarly, research on alternative binders and non-Portland cementitious materials has highlighted their potential to reduce the environmental impacts associated with conventional cement production [21].



Figure 1. Recycled Aggregates



Figure 2. Fresh Concrete Containing Recycled Aggregates

From a structural performance perspective, studies on recycled aggregate concrete indicate that it can be used in structural elements, provided that appropriate design requirements and quality control measures are implemented. Xiao et al. investigated the seismic performance of structures made with recycled aggregate concrete and demonstrated the feasibility of using this material in frame structures when its mechanical properties are adequately characterized and incorporated into the design process [22]. This finding is particularly important because it expands the application of recycled aggregates beyond non-structural uses.

Effective construction and demolition waste (CDW) management is not limited to the recycling of materials after demolition but should be integrated from the design stage of a project. Llatas and Osmani proposed a waste reduction model based on building design, emphasizing that decisions made during the early stages of a project can significantly influence the amount of waste generated throughout the construction process [23]. Furthermore, studies focusing on the quantification of waste generated during the

construction of high-rise buildings indicate that statistical models can support the estimation and control of waste quantities from the planning phase onward [24].

Life Cycle Assessment (LCA) studies indicate that the use of recycled aggregates can contribute to reducing the consumption of natural resources and mitigating the environmental impacts associated with waste transportation and disposal [9]. However, the environmental benefits depend on several factors, including transportation distances, the energy required for crushing and sorting operations, the quality of the recycled material, and the replacement rate of natural aggregates [9]. Therefore, waste valorization should be evaluated not only from a technical perspective but also from economic and environmental viewpoints.

The analyzed results show that construction and demolition waste can be valorized through several pathways, including the use of recycled aggregates in concrete production, asphalt recycling, the reuse of bricks and ceramic materials, metal recovery, wood valorization, and the incorporation of alternative materials into cementitious products [7,8,10,25]. Among these options, concrete recycling in the form of recycled aggregates is considered one of the most extensively studied and promising solutions due to the large quantities of concrete generated during demolition activities and the possibility of reintegrating it into new construction materials [11-14,26].

The scientific literature confirms that construction and demolition waste should not be regarded solely as residual materials but rather as secondary resources with significant potential for reintegration into the economic cycle. Nevertheless, their large-scale utilization requires clear quality standards, efficient sorting and processing technologies, rigorous control of recycled material properties, and acceptance by designers, contractors, and end users. Through the implementation of these measures, construction and demolition waste (CDW) management can significantly contribute to reducing environmental impacts and promoting the development of a more sustainable construction sector [10], [5,6,9,11]. The transition from a linear to a circular construction model requires not only technological innovation but also systemic changes in design practice, material standards, and stakeholder collaboration.

CONCLUSIONS

Construction and demolition waste (CDW) management represents a fundamental component of sustainable development within the construction industry, contributing to the reduction of environmental impacts, the conservation of natural resources, and the promotion of circular economy

principles. Given the substantial quantities of waste generated by this sector, the implementation of efficient management and valorization systems has become both an economic and an environmental necessity.

The literature review highlighted that effective construction and demolition waste management should encompass measures aimed at waste prevention, selective collection, sorting, reuse, recycling, and the recovery of valuable materials. The application of the waste hierarchy enables a reduction in the quantities of waste sent to landfill while increasing the recovery rate of materials that can be reintegrated into the economic cycle.

The results of this study indicate that one of the most effective valorization methods is the recycling of concrete and the use of recycled aggregates in the production of new construction materials. Furthermore, other waste streams, such as asphalt, metals, wood, bricks, and ceramic materials, also exhibit considerable potential for reuse and recycling. The valorization of these materials contributes to reducing raw material consumption, minimizing environmental impacts, and improving resource-use efficiency.

The reviewed studies indicate that the success of construction and demolition waste (CDW) management depends not only on the performance of recycling technologies but also on the existence of appropriate policies, effective regulations, and close collaboration among public authorities, designers, contractors, and waste management operators. Integrating circular economy principles from the early design stages of construction projects can significantly contribute to reducing the amount of waste generated and increasing the rate of material valorization and recovery.

Construction and demolition waste management should be regarded as an essential tool for the development of a more sustainable construction sector. The implementation of effective waste management and valorization strategies can transform these materials from an environmental burden into valuable resources, contributing to environmental protection, the reduction of natural resource consumption, and the advancement of a functional circular economy.

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Faculty of Engineering Hunedoara,
5, Revolutiei, 331128, Hunedoara, ROMANIA
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