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## Development of technologies for processing construction and demolition waste in the Republic of Moldova

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**Abstract.** In the global context, characterized by accelerated urbanization, depletion of natural resources and worsening climate change, the construction sector plays a significant role in achieving sustainable development. In the context of issues related to ensuring sustainable development, one of the important directions is the problem of waste that persists in practically all areas of socio-economic life. Taking into account the importance of developing waste management in the construction sector, the development of technologies for processing construction and demolition waste will significantly reduce the amount of unprocessed waste, global CO<sub>2</sub> emissions and will bring multiple benefits in terms of saving natural resources. This article addresses the situation regarding the main categories of waste, the main causes of construction and demolition waste generation, analyzing the main technologies for their processing, which, in the Republic of Moldova, are at an early stage of development. At the same time, the article analyzes the innovative solutions regarding the use of recycled materials in construction, demonstrating their role in promoting urban sustainability. The study examines the trends and innovative models, with the aim of showing how recycled materials can contribute to the development of green and sustainable cities.

**Keywords.** processing technologies, recycling, construction and demolition waste, reuse, waste management, recycled materials, sustainability

### Introduction

According to Eurostat data, the construction sector generates more than 35% of total solid waste in the European Union. The production of construction materials is responsible for approximately 11% of global CO<sub>2</sub> emissions. The construction industry also consumes over 50% of the raw materials extracted worldwide, which increases the pressure on ecosystems [1]. The environment has become a huge challenge and is, at the same time, a topic of general interest. Currently, waste represents a major problem for society, given that its inadequate management has extremely harmful effects on the environment. The amount of waste is increasing rapidly, directly proportional to the increase in the level of well-being, having an increasingly pronounced negative impact on the environment. In this context, Waste Management has become a key element for ensuring sustainable growth of the country's economy [2].

Based on this fact, the use of recycled materials from construction and demolition is no longer just an ecological alternative, but a strategic necessity. For example, recycled concrete and reinforced concrete can reduce greenhouse gas emissions by up to 65% compared to standard concrete. Reusing steel can contribute to a reduction in carbon emissions by up to 90%. In addition, the use of recycled glass can reduce energy consumption by 2-3% for every 10% of recycled glass used in the manufacturing process, raw material consumption, each ton of recycled glass saves over a ton of natural resources and reduces the amount of waste in landfills [1]. Around the world, more and more initiatives are focused on discovering and developing innovative solutions and technologies that use recycled materials. Waste management in construction is an essential component of sustainable development and an important factor in the environmental responsibility of the construction industry.

These approaches arise in response to the challenges of pollution, excessive resource consumption and the need for sustainable construction. Recycled materials thus become a valuable resource, being integrated into new, efficient and less environmentally harmful products.

### 1. Analysis of statistical data on construction and demolition waste and the causes that generate it, at the level of the Republic of Moldova

In the Republic of Moldova, the Automated Information System for Waste Management (AIS WM) responds to the need for efficient waste management, providing a unified system that covers various aspects, from the authorization of waste management activities to the reporting of the results obtained in this field. Thus, based on the data reported by enterprises, the Environmental Agency generalizes and presents statistical information on waste management. In 2024, enterprises in the Republic of Moldova generated a total of 372.4 thousand tons of waste, which represents an increase of approximately 41% compared to the previous year [3].

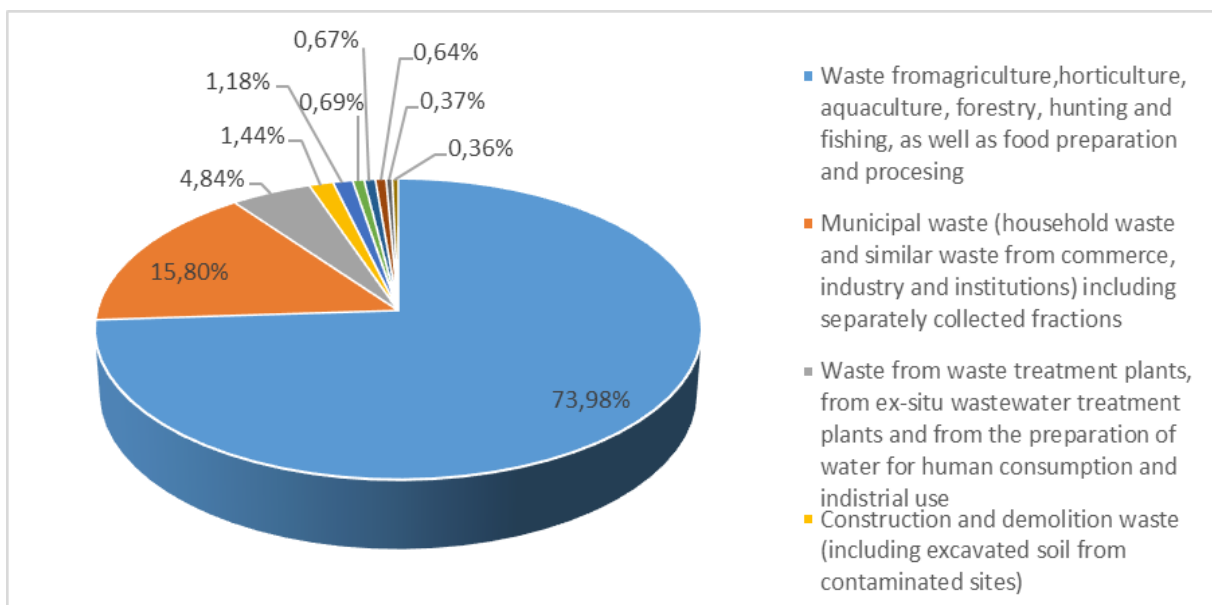


Figure 1. The structure of waste generated by enterprises in the Republic of Moldova by activity groups.

Figure 1. shows that out of a total of 372.4 thousand tons, 1.44% is construction and demolition waste (5,358.05 t) [3]. Construction and demolition activities generate a wide variety of waste, influenced by the nature of the project, the technologies used, the quality of execution and the way the construction site is organized. This waste has a different composition, volume and potential for recovery, which makes it difficult to manage. Understanding the sources of generation and classifying waste types is essential for implementing an efficient system of collection, sorting, recycling and disposal. In addition, the large amount of construction waste negatively affects the environment by occupying storage spaces, polluting the air and soil, but also by the intense consumption of non-renewable resources. If not managed properly, this waste can contribute to greenhouse gas emissions and degrade the urban and rural landscape. Another important aspect is the economic impact - the costs of transportation, storage and disposal of waste increase significantly in the absence of a prevention and reuse policy [4].

The main causes of waste generation in construction and demolition in the Republic of Moldova are:

1. *Poor design and planning* - Errors occurring in the design phase can lead to subsequent changes in execution, which involve the replacement or elimination of already installed elements, thus generating material losses and additional costs. A common example is the design of construction elements incompatible with the standard dimensions of the materials available on the market, which leads to adjustments to the construction site and, implicitly, to the generation of waste (for example, cuts of ceramic tiles, drywall, OSB panels, etc.). Another important factor is the lack of correlation between design specialties (architecture, installations, structure), which can lead to overlapping technical routes, requiring subsequent changes on the construction site. Also, underestimating the required quantities or oversizing orders out of prudence or lack of experience leads to the accumulation of unused materials, which risk becoming waste if not properly stored or returned [5]. In practice, situations have frequently been observed in which the lack of precise technical details in the project - such as joint details, tolerances or assembly specifications - has led to incorrect execution or partial rework. This contributes not only to waste of materials, but also to delays in the works and an increase in the total costs of the project. A concrete example can be observed in public projects in the Republic of Moldova, where procurement procedures and the lack of rigorous control over the design phase often lead to revisions during the execution phase. Also, the absence of standardized design guidelines for resource-efficient constructions leads to large variations in material consumption and, implicitly, in the amount of waste generated. Furthermore, design without a sustainable approach – including material reuse, modularity of elements or selective dismantling options – limits the possibility of subsequent recycling. The lack of use of modern tools, such as building information modeling (BIM), maintains a high level of uncertainty regarding the actual quantities of materials needed and potential losses [6].

2. *Incorrect handling, transportation and storage* - These aspects are often underestimated, although they directly influence both the efficiency of execution and the amount of waste produced.

During the supply and delivery stage, inadequate packaging of fragile materials (e.g. windows, tiles, faience, sanitary ware) frequently leads to their damage during transport. Improper unloading or the lack of adequate equipment (e.g. cranes, site lifts, forklifts) causes the materials to break, shatter or deform, which can then no longer be used according to their original purpose. On site, the materials are stored in unfavourable conditions - uncovered, on wet ground, in unsecured spaces - which exposes them to humidity, frost, dust or vandalism [5]. For example, wood exposed to repeated rain becomes unusable due to deformation or the

appearance of mould. Mortars or adhesives left in open bags lose their chemical properties and can no longer be used, turning into waste. Another critical aspect is the lack of a clear organization of stocks on site. Materials are often mixed or placed in hard-to-reach places, which leads to their damage during relocation or the impossibility of their use on time. As a result, many products remain unused and ultimately become waste. In practice, the lack of training of workers on the correct handling of materials contributes to this phenomenon. Also, the absence of rigorous procedures for receiving materials and the lack of a monitoring of storage conditions can lead to significant losses, which negatively affects not only the environment, but also the project budget.

3. *Execution and commissioning activities* - The actual execution phase of the works is usually the stage that generates the largest volume of waste in construction. This is due to the large number of manual and mechanized operations, the variety of materials used in the work, but also to human or technical factors that can negatively influence the efficiency of resource use. Among the most common sources of waste in this stage are the remains of materials resulting from cutting, shaping or adjustment (e.g. ceramic tiles, gypsum boards, expanded polystyrene, wood, metal profiles), as well as residues from the preparation of mortar, concrete or plaster, which are not fully used and harden before commissioning [5]. In addition, there is the packaging of the materials - cement bags, plastic films, cardboard boxes - which, although partially recyclable, often end up mixed with other waste, becoming difficult to recover. Execution errors also play an important role in waste generation. Incorrect measurements, incorrect application of finishing layers, defective concrete castings or non-compliant assembly of elements may require the re-doing of significant portions of the work. These re-does not only require additional consumption of materials and time, but also the elimination of those already used, which have become unusable. Another important aspect is the lack of reuse practices on the construction site. Often, materials left over from activities – such as wooden formwork or guide rails – are discarded, although they could be used in other phases of the work. In the absence of an organizational culture oriented towards efficiency and minimizing losses, such practices remain rare in the construction sector, especially in the context of the Republic of Moldova, where legislative pressures on waste management are still low [7]. It is also worth noting the contribution of weather conditions or disorganized work schedules to the increase in the amount of materials damaged or lost during execution. For example, a delayed concrete pour due to weather conditions can lead to premature hardening of the prepared material, which then becomes waste. Therefore, the execution phase is critical from a waste prevention perspective and requires an integrated approach, which includes both training of workers and the implementation of clear procedures for the efficient use of resources.

4. *Repairs, renovations and demolitions* - Repairs, renovations and demolitions are activities that generate significant amounts of waste, often heterogeneous, bulky and difficult to separate. They represent a major challenge for the sustainable management of construction and demolition waste, as the resulting materials are often contaminated, damaged or irreversibly combined. In the case of repairs and partial renovations – whether in residential buildings or commercial spaces – old finishes (e.g. tiles, faience, plaster, parquet, paneling), outdated electrical and sanitary installations, deteriorated joinery or plasterboard partitions are frequently removed [5]. These materials are rarely reusable and, in the absence of an efficient sorting system on the construction site, they end up mixed, contaminating each other and becoming impossible to recycle. Complete or partial demolitions generate an even larger flow of waste, especially of mineral type – reinforced concrete, brick, stone, mortars, plasters – but also metal components, wood, glass, plastic, cables and pipes. The major problem is that many of these

materials are still joined together (e.g. concrete with metal reinforcement, masonry with plaster and paint), which makes sorting and subsequent treatment difficult. Particularly problematic is the presence of hazardous or difficult-to-recycle materials, frequently found in old buildings. These include:

- asbestos-cement panels and tiles (contain asbestos, a carcinogenic material);
- polyurethane foam, used as insulation or adhesive;
- paints with high lead content;
- degraded or outdated plastic materials, which become brittle;
- old electronic components and sanitary equipment, which may contain heavy

metals.

In the Republic of Moldova, where many Soviet-era buildings are undergoing renovation or demolition, such materials are common and require specific, expensive and often inaccessible treatment for small developers or private owners. In the absence of a clear legislative framework and a well-developed selective collection infrastructure, this waste is often abandoned or transported directly to landfills, without prior sorting or neutralization. Another important aspect is that during renovation works, spaces are often partially occupied, and efficient waste collection is limited by restricted access, lack of temporary storage space and the fast pace of work [8]. These conditions lead to chaotic waste management, with a high risk of cross-contamination and loss of recycling potential.

5. *Indirectly generated waste* - In addition to the waste resulting directly from construction activities, a significant volume - although often underestimated - is represented by the waste generated, indirectly, collaterally, as a result of auxiliary activities carried out on the construction site. Although this waste is generally in smaller quantities compared to that resulting from demolition or execution, it can have a disproportionate impact on the environment and the recycling potential, due to its often hazardous or difficult-to-recover nature. This category primarily includes the packaging of construction materials: plastic or paper bags (for cement, plaster, adhesives), cardboard boxes, protective foils, adhesive tape, wooden pallets, metal containers for paints or adhesives. In the absence of separate collection, this packaging ends up mixed with other waste, being dirty, contaminated with chemicals or destroyed, which makes it difficult or impossible to recycle [5]. Another important type of indirect waste is represented by the worn or damaged personal protective equipment – gloves, overalls, masks, helmets, visors, boots, etc. These, although essential for work safety, become non-recyclable waste after use and most often end up in final storage, without sorting or energy recovery. This category also includes consumables used daily on the construction site: paper rolls, filters, bags, plastic containers, cleaning solutions, cloths soaked with toxic substances, as well as expired or unused paints, adhesives or thinners [9]. Many of these contain volatile organic compounds, heavy metals or other toxic substances that, without an adequate collection and treatment system, can contaminate soil and groundwater. Another example of indirect waste is water used to clean tools and equipment, which, although not solid waste, can become a hazardous liquid waste if it contains paint, mortar, cement or other chemical residues. This wastewater requires filtration or neutralization before disposal, but in many cases it is simply dumped into the network or the environment, contributing to pollution. Thus, the high level of construction activity around the world results in a large volume of waste generated following construction or demolition. All construction, demolition, restoration and reconstruction projects generate a lot of waste [8]. Statistical data on the percentage of waste from construction or demolition are presented in Figure 2.

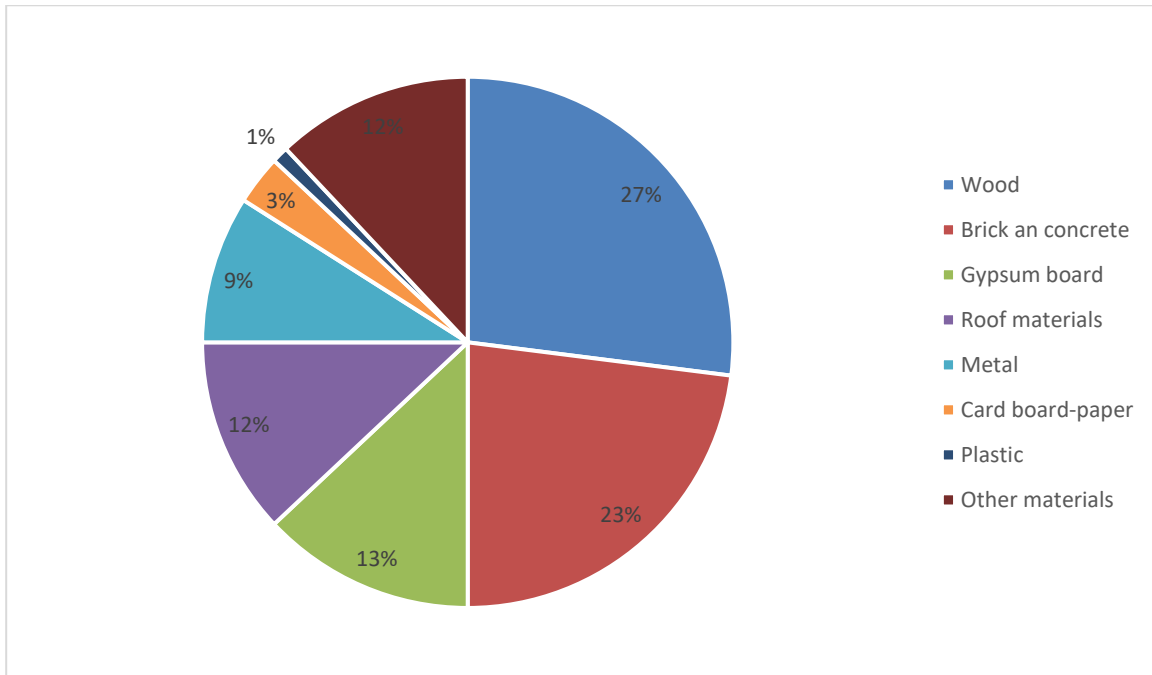


Figure.2: The structure of construction and demolition waste by material categories obtained in the Republic of Moldova in 2024. [9]

The largest part of the structure of construction and demolition waste by material categories, obtained in the Republic of Moldova in 2024 is wood - 27% of the total volume of construction and demolition waste. It is followed by brick and concrete, with a share of 23% of the respective structure, plasterboard - 13%, roofing materials - 12%, metal -9%, cardboard and paper in a proportion of 3%, plastic -1% and in a proportion of 12% other materials [10].

Analysis of recycled resources and recycled materials that can be used in construction represents an important step towards sustainable development and resource saving. There are many materials that can be reused in construction, reducing the costs of extracting new resources and reducing the amount of waste. The main recyclable materials resulting from construction and demolition and potential methods for obtaining recycled materials are presented in Table 1.

Table 1. The main recyclable materials, origin and recycling methods

Recyclable materials	Origin	Recycling methods
Reinforced concrete/steel	Reinforced concrete structure reinforcement, metal scaffolding	Collection and melting in industrial furnaces to obtain reusable steel (bars, profiles, etc.)
Concrete	Demolition of old floors, columns and load-bearing walls	Crushing and transformation into recycled aggregates used for road foundations or technical fills.
Wood	Old beams, doors, formwork	a. Reuse as pallets or panels;

		b. Crushing and transformation into biomass (briquettes, pellets); c. Composting (in the case of chemically untreated wood).
Glass	Old windows, broken mirrors	Color sorting, grinding and melting for the manufacture of new glass products (windows, mineral wool, etc.)
Brick and ceramics	Old masonry, ceramic tiles in bathrooms and kitchens	Grinding and use as filler or paving material in road construction.
Card board - paper	Packages	Recycling into new paper products.
Plastic	PVC pipes, protective film, packaging.	Sorting by type (PET, HDPE, PVC), washing and grinding, then reuse to obtain secondary plastics.
Gypsum board	False ceilings and insulated walls	After removing the cardboard and shredding, used to make new walls After shredding, used as an absorption product

Source: developed by the author based on [11]

Recycling (secondary processing of the material) allows for more rational use of non-renewable natural resources and minimizes environmental damage caused by production activities. Smart recycling can reduce the cost of construction, making construction and demolition waste a fairly attractive source for urban renewal and regeneration [12].

Table 2. Structure of construction works by categories of works performed in the Republic of Moldova in 2021-2024, %

Types of construction work	2021	2022	2023	2024
New buildings	45,1	51,2	51,9	57,2
Major repairs	27,9	25,3	24,9	23,6
Current repairs and maintenance	24,8	23,1	24,1	23,8
Other works	1,9	1,9	1,9	2,2

Source: developed by the author based on [11]

Analyzing the distribution of types of construction works in the period 2021-2024, (table 2.) at the national level, we can state that new construction works have experienced a constant increase in the last four years, from 45.1% in 2021 to 57.2% in 2024, holding the largest proportion of total construction works. Capital repair works have experienced a decrease

from 27.9% in 2021 to 23.6% in 2024. The same downward trend can be observed in current repair and maintenance works, from 24.8% in 2021 to 23.8% in 2024. Other works register a slight increase in 2024, although they represent a small share of total construction works. These trends reflect changes in the construction sector in the Republic of Moldova, which may affect the type of waste generated and the availability of recycled materials in the construction industry.

## **2. Modern equipment and technologies for the recovery of concrete and used reinforced concrete.**

In recent years, the process of industrialization and urbanization has been intensifying in the Republic of Moldova. According to the National Bureau of Statistics, by structural elements of the works performed, in 2024 compared to 2023, the volume of new construction works increased by 5.3%, and of the total volume of works performed in 2024, the largest share belongs to new construction works, which constituted 57.2%. The vast majority of new constructions are buildings made mainly of reinforced concrete, since this material is the most efficient and practical construction solution in all countries of the world [10]. But, inevitably, we ask ourselves: *What will happen to the large quantities of concrete and reinforced concrete waste, when new buildings will be built in place of the old constructions?*

The answer to this question can come precisely through the recycling of concrete and reinforced concrete waste, with a view to reuse.

Recycled concrete is obtained from used concrete from demolitions, crushed (figure 3), sorted by magnetic separators, sieves and/or optical sensors, and in some cases the aggregates are treated with sodium silicate to increase their adhesion to the new binder. It is used in the construction of roads and highways (as a base layer or fill), in prefabricated elements (masonry blocks). The advantages include: reduced extraction of natural aggregates, strength approximately equal to standard concrete. Another alternative would be to transport the concrete resulting from demolitions to a special crushing station (figure 4), obtaining recycled aggregates for use in infrastructure.



Figure 4. Fixed concrete recycler. [14]



Figure 3. Concrete crushing. [14]

Recycled reinforced concrete can contribute to reducing the use of raw materials, which will result in the conservation of natural resources and a net reduction in greenhouse gas emissions. For example, the production of one ton of steel reinforcing bars requires approximately 2,500 kilograms of iron ore, 1,400 kilograms of coal, and 120 kilograms of limestone. Taking into account the fact that the used reinforced concrete cannot be used in the resistance structure of a building, with the same efficiency, it will be recycled to be reused in

the composition of materials with lower performance, such as substrates, asphalt, etc. Therefore, the use of such a material may be limited by the fact that recycled concrete does not have exactly the same properties as classic concrete, showing a decrease in flexibility and a high shrinkage. However, as the experience of some construction sites has shown, even in places where 100% recycled concrete was used, there is no risk of deformation and cracking [13].

Recycling reinforced concrete also offers economic benefits, since recycled crushed concrete stone, in terms of characteristics, is not inferior to natural stone, but its price is 5-8 times lower. Recycled material can be used as an aggregate for concrete production, reducing its cost by approximately 25%. Thus, recycled concrete will not only not end up in landfills, but will also successfully replace other materials, such as gravel, which otherwise must be extracted and transported for use. Also, the dust produced after crushing used concrete can be used as aggregate in concrete mixtures, and can be used in the construction of roads, asphalt, in the construction of wells, dams and artificial reservoirs.

According to the Steel Recycling Institute, today more than 65% of rebar is recycled worldwide, over 7 million tons of scrap iron are recycled into reinforcing bars each year, and nearly 100% of the raw material used to produce rebar comes from recycled ferrous waste. These aspects are particularly important in view of the depletion of natural resources. Recycling of these materials is carried out with the help of specialized equipment (figure 5), [14] such as crushing plants (jaw crushers, impact crushers, hammer and cone crushers, into the chambers of which pieces of reinforced concrete of limited dimensions can be loaded) and sorting or technological lines. Crushing and screening lines are usually stationary equipment, while complexes can be mobile. It is certainly more efficient to use mobile units, as they can be transported directly to the construction site, thus reducing the costs of transporting waste to collection centers. The extraction of metal reinforcement inclusions is carried out by screening. After crushing, the crushed stone of a certain fraction falls onto the pallet, while the metal remains on the grid, which is subsequently collected, crushed and sent for melting. The same technology can use a magnetic separator to separate metallic materials found in crushed reinforced concrete directly from the conveyor belt.



Figure 5. Reinforced concrete crushers. [14]

In the case of using recycled materials in construction, today there are a number of technical, logistical and infrastructural, economic and legislative and regulatory challenges.

*Technical challenges:* Recycled materials, such as aggregates obtained from concrete, reinforced concrete, ceramics, glass or plastic have a non-uniform composition, increased

porosity and poor adhesion to the cement binder. This affects the strength and durability of the obtained materials (recycled concrete aggregates may contain old mortar, impurities and water). Possible solutions to remedy the challenge would be: coating the aggregates with adhesion agents to improve the bond with the cement paste; using optical sensors for more precise separation of materials, resulting in homogeneous aggregates; adapting the mixing proportions depending on the properties of each recycled material.

*Logistics and infrastructure challenges:* In many regions of the Republic of Moldova, specialized and developed facilities for the collection, sorting and recycling of construction and demolition waste are lacking. Also, the transportation of this waste is expensive and polluting. Possible measures to solve these problems are: placing mobile crushing stations directly on the construction site (if possible); setting up more recycling centers or improving and developing existing ones with specialized facilities for sorting and processing recyclable waste; digitalizing the process of monitoring recycled materials, contributing to more efficient logistics and selective recycling.

*Economic challenges:* Recycling can be perceived as more expensive than storage (transport, sorting). The proposed solutions are: higher storage fees for unsorted waste, to encourage recycling; financial support for enterprises that use a certain, minimum amount of recycled materials. Legislative and regulatory challenges: The lack of clear standards for the use of recycled materials stops their use in various projects. Possible options to remedy the challenges would be: developing standards and regulations for each type of recycled material; establishing a mandatory minimum percentage of use of recycled materials in public projects [15].

## **Conclusion**

Construction, demolition of buildings, dismantling of structures are accompanied by the accumulation of concrete and reinforced concrete elements. Due to the large weight and volume, waste disposal requires significant financial investments. Recycling of concrete and reinforced concrete directly influences the costs of construction materials and is reflected in the conservation of natural resources. Various studies have been conducted and numerous solutions have been researched, highlighting the possibility of creating new technologies with practical applicability, in order to implement and use the recycled materials, such as concrete aggregates and crushed reinforced concrete. They represent a trend towards reducing the consumption of natural resources and the environmental impact of the construction sector. However, to achieve this goal, it is necessary to overcome a series of technical, economic, logistical and legislative challenges, mentioned in this article. Construction and demolition waste is a major environmental problem, with estimates showing that construction and demolition activities generate approximately 40% of the world's waste. The circular economy offers a promising solution to this problem by keeping resources in use for as long as possible and by minimizing waste. By adopting the principles of the circular economy, the construction industry can reduce its environmental impact, while creating new economic opportunities. However, the reuse of construction and demolition waste, as well as the partial or even total replacement of standard materials, will contribute to reducing carbon emissions and reducing the volume of waste in landfills, having, in turn, a positive impact on the environment. Recycling not only solves environmental or economic problems, but also increases people's confidence in the quality of recycled construction materials and, last but not least, encourages us to be more environmentally responsible. This will bring us closer to a sustainable and green future, in which urban areas will become more ecological, more efficient and in harmony with nature.

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