

CONSTRUCTION, DEMOLITION, AND RENOVATION WASTE

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Jasmina Radosavljević, Ana Vukadinović

University of Niš, Faculty of Occupational Safety, Niš, Serbia

ORCID iDs: Jasmina Radosavljević
Ana Vukadinović

<https://orcid.org/0000-0001-8545-2265>
<https://orcid.org/0000-0002-6228-1077>

Abstract. *Increased construction and demolition activities have led to a rise in construction and demolition waste. Construction waste is generated during the construction, adaptation, and demolition processes. Its quantities depend on the materials used, construction techniques, and types of projects. In Serbia, the management of such waste is regulated by specific legislation. This paper provides a classification of construction waste according to the European waste catalog and describes its generation, management, and the possibilities for estimating waste before the commencement of construction work. The possibilities and main obstacles to recycling this waste are also described.*

Key words: *C&D (construction and demolition) waste, C&D waste management plan, estimation of C&D waste quantities, C&D waste recycling*

1. INTRODUCTION

The problem of waste generation, including waste from construction, renovation, and demolition of buildings, is a global issue. Construction waste encompasses all waste generated as a result of demolition, construction, and renovation activities in Europe, accounting for 25-30% of total generated waste. Accordingly, the construction industry significantly contributes to environmental degradation and the consumption and depletion of natural resources [1-2].

- Construction waste is generated as a result of works carried out on buildings from the foundation upwards, as well as civil engineering works such as the construction of roads, railways, canals, dams, sports and recreation facilities, ports, airports, and the like. The composition of construction waste depends on the type of construction work and the techniques used. Construction waste is classified based on its content

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Corresponding author: Ana Vukadinović
Faculty of Occupational Safety, Čarojevića 10a, 18000 Niš, Serbia
E-mail: ana.vukadinovic@znrfak.ni.ac.rs

and composition according to the European waste catalog. It is divided into five main categories:

- Soil (sand, clay, stones, mud, etc.) is generated from pre-construction excavations. This waste can be mixed with organic plant elements.
- Packaging waste from construction materials (wooden pallets, plastic, cardboard, etc.) that are less prevalent in construction works.
- Residual construction materials (natural stone: concrete, ceramics, aggregates and their mixtures; non-stone: steel, iron, aluminum, copper, glass, wood, plastic, asphalt, etc.), which are more homogeneous in construction works.
- Hazardous waste (contaminated soil and excavations, materials and substances with potentially hazardous characteristics: flammable concrete additives, adhesives (flammable, toxic, or irritating), tar emulsions (toxic, carcinogenic), asbestos-based materials in breathable fiber form (toxic, carcinogenic), wood treated with fungicides, pesticides, etc. (toxic, ecotoxic, flammable), coatings with halogenated flame retardants (ecotoxic, toxic, carcinogenic), equipment with PCBs (ecotoxic, carcinogenic), mercury lighting (toxic, ecotoxic), systems with CFCs, gypsum components (possible sources of sulfides in landfills, toxic, flammable), containers for hazardous substances (solvents, paints, adhesives, etc.), and contaminated waste packaging.
- Other (organic materials) [3-4].

Construction waste can be generated due to:

- Material losses during transport to the construction site, unloading, and initial storage.
- Improper storage of materials leads to material loss due to exposure to rain and/or pedestrian/vehicle traffic.
- Cutting of materials into different sizes and uneconomical shapes.
- Improper enclosure of remaining materials in containers and metal boxes, causing hardening of excess materials left after use.
- Damage caused by subsequent works.
- Theft and vandalism.
- Lack of supervision or incorrect management decisions.
- Improper use or incorrect selection of materials.

Construction and demolition (C&D) waste constitutes more than one-third of the total waste generated in the European Union. In recent years, there has been a construction boom in Serbia, increasing the demand for construction materials. Additionally, the amount of demolition waste has increased. Increased construction and demolition activities have led to a rise in C&D waste. Large quantities of construction waste end up in landfills, by roadsides, and in nature. However, large portions of this waste can be reused. According to estimates, around 3 to 4 million tonnes of construction waste are generated annually in Serbia, not only from demolition and construction but also from major infrastructure works, such as road and railway construction, as well as works like water and sewage construction, resulting in a significant amount of waste.

Materials such as concrete, bricks, wood, glass, metals, and plastics, essentially all waste generated from the construction and demolition of structures and infrastructure, as well as from planning and maintenance of roads, end up in landfills. Through recycling, all of this waste can be reused, thereby preserving resources and protecting the environment. In some European countries, like the Netherlands and Denmark, up to 90%

of the total amount of construction waste is recycled. This type of waste is a national resource that should be utilized, and the first steps in solving the problem of construction waste management involve amending the relevant legislation.

The Government of the Republic of Serbia adopted the Regulation on the Manner and Procedure for Construction and Demolition Waste Management, which for the first time stipulates how this waste should be managed. The goal of the Regulation is to prevent the creation of illegal landfills and to allow the waste to be used in construction. The aim of the Regulation is to change habits, existing practices, and rules so that construction waste in this case becomes a resource.

Among other things, the amount of construction waste can be reduced through proper management of waste materials on construction sites. Investors are legally required to develop a Construction and Demolition Waste Management Plan.

2. CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT PLAN

Construction waste is generated from construction and other works related to building construction and demolition, adaptation, renovation, and reconstruction; construction, maintenance, and replacement of infrastructure facilities; excavations for residential, industrial, and road infrastructure construction; and demolition of built structures.

The management of construction waste involves a set of activities and measures that include separate collection, sorting, transport, storage, preparation for reuse, recycling, and/or disposal of construction waste.

Measures for C&D waste management include:

- Extracting useful components from and within the building before starting construction and other works, which are not considered waste according to the law regulating waste management and which can be reused for the same purpose for which they were produced (bricks, tiles, etc.).
- Preventing the mixing of hazardous and non-hazardous C&D waste and the mixing of different types of waste.
- Preventing the dispersal, spillage, and leakage of hazardous waste into the soil, surface and groundwater, and air.
- Determining the location for temporary storage of C&D waste at the site of generation, i.e., at the construction site.
- Testing and classifying C&D waste.
- Carrying out works in a way that prevents waste generation.
- Encouraging the reuse and recycling of C&D waste.
- Keeping records and reporting on the quantity and type of generated C&D waste, as well as the treatment it has undergone [5].

C&D waste should be separated at the site of generation to prepare it for treatment, i.e., reuse, including processes like backfilling and disposal. Uncontrolled disposal of such waste is prohibited.

Figure 1 shows the demolition works.



Fig.1 Demolition works. [6]

According to the Law on Waste Management, Article 58a (“Official Gazette of the RS”, No. 36/2009, 88/2010, 14/2016, 95/18 – other law, and 35/2023), which stipulates the management of C&D waste, and according to the Regulation on the Manner and Procedure for Construction and Demolition Waste Management (“Official Gazette of the RS”, No. 93/2023 and 94/2023 – corrected), a C&D Waste Management Plan is developed and is part of the documentation submitted with the application for obtaining a construction permit. According to Article 6 of the Regulation on the Manner and Procedure for Construction and Demolition Waste Management (“Official Gazette of the RS”, No. 93/2023), the producer of C&D waste (the investor, the owner of the C&D waste) is required to develop a C&D Waste Management Plan, obtain approval for the Plan, and organize its implementation if the works are carried out on a category B, V, and G building according to the Rulebook on Classification of Buildings (“Official Gazette of the RS”, No. 22/2015). The approval decision for the C&D Waste Management Plan is submitted along with the application for the construction permit or the decision on approval for construction.

The C&D Waste Management Plan contains information on:

- The type and planned quantity of waste that will be generated by activities on the construction site during construction, demolition, adaptation, reconstruction, and other works on a building or part of a building.
- The location of containers for collecting C&D waste.
- The method of separate waste collection, preparation for transport, and temporary storage of the waste in question.
- Handling of hazardous waste that is expected to be generated during the execution of works.
- Methods for reusing C&D waste.
- The quantity and type of C&D waste planned to be handed over to an operator of a facility for the reuse of waste, i.e., planned quantities sent for processing/recycling.
- The intended methods for C&D waste treatment.
- The estimated volume of soil excavation, resulting from construction works on the site, and its handling [5, 7, 8].

3. ESTIMATION OF THE QUANTITY OF CONSTRUCTION WASTE GENERATED AT CONSTRUCTION SITES

The types and quantities of waste generated at construction sites depend on the characteristics of the materials used and the construction techniques employed during the construction process. Thus, the waste will vary depending on the project. There are generally two procedures for estimating the quantities of waste generated:

- Quantification procedure for obtaining approximate estimates using waste quantification tables.
- Quantification procedure for obtaining specific estimates for each project.

The methodology for such cases is as follows:

- Step 1: Obtaining waste quantification tables classified by type of project (demolition, construction, renovation); purpose (residential, nonresidential: industrial, commercial, etc.); and relevant technologies for the project (prefabricated construction, masonry, etc.).
- Step 2: Identifying the characteristics of the project: type of project (demolition, construction, renovation); purpose (residential, nonresidential: industrial, commercial, etc.); and main technologies (usually construction-related: metal, concrete, or masonry).
- Step 3: Calculating the project area (in m²).
- Step 4: Obtaining the total quantity of waste (volume and/or weight) from the floor area of the project.
- Step 5: Determining the composition of the waste (quantities by type of waste) [9].

Waste quantification tables (Tables 1 and 2) can be used to obtain approximate data on C&D waste.

Table 1 Weighted average C&D (construction and demolition) waste generation rates (kg/m²) [9]

Type of construction	Heavyweight construction: masonry, concrete, etc.		Lightweight construction: precast elements, drywalls, wood frame, etc.	
	Residential building	Nonresidential building	Residential building	Nonresidential building
New building construction	120-140	100-120	20-22	18-20
Rehabilitation	300-400	250-350	90-120	80-90
Demolition	800-1000	500-700	500-700	700-800

Table 2 Volume average C&D (construction and demolition) waste generation rates (m³/m²) [9]

Type of construction	Heavyweight construction: masonry, concrete, etc.		Lightweight construction: precast elements, drywalls, wood frame, etc.	
	Residential building	Nonresidential building	Residential building	Nonresidential building
New building construction	0.12-0.14	0.10-0.12	0.02-0.03	0.02-0.03
Rehabilitation	0.30-0.40	0.25-0.35	0.10-0.15	0.09-0.10
Demolition	0.80-1.00	1.00-1.20	0.50-0.70	0.70-0.08

Table 3 shows the average composition of construction waste by volume in construction.

Table 3 Rounded average percentage of waste composition by volume in constructions (%) [9]

Type of waste	Heavyweight construction: masonry, concrete, etc. (%)	Lightweight construction: precast elements, drywalls, light frame, etc. (%)
15 Packaging waste	60-70	30-60
15 01 01 Paper cardboard pack	2-4	1-4
15 01 02 Plastic packaging	5-7	2-3
15 01 03 Wooden packaging	50-55 and 17 02 01 wood*	25-45
15 01 04 Metallic packaging*	2-3 and 17 04 metals	2-7
15 01 06 Mixed packaging	< 1	< 1
17 C&D waste	30-40	40-70
17 01 01 Concrete	15-20	10-30
17 01 03 Ceramics-bricks	10-13	-
17 01 07 Mixed concrete, ceramics	2-3	-
17 08 02 Drywalls	-	20-25
17 09 04 Mixed C&D waste	3-4	10-15
17 05 Soil and stones	Varies	Varies

Table 4 Rounded average percentage of waste composition by volume in demolitions (%) [9]

Type of waste	Residential		Nonresidential	
	Masonry (%)	Concrete (%)	Metal (%)	Concrete (%)
17 01 01 Concrete	5-10	40-50	15-20	35-40
17 01 03 Ceramics-blocks mixtures	65-70	20-30	15-20	5-10
17 01 07 Concrete-ceramics	5-10	5-10	35-40	40-45
17 02 01 Wood	1-5	1-5	0.3	0.2
17 02 02 Glass	0.1	0.1	0.2	0.1
17 02 03 Plastics	0.1	0.1	0.8	0.8
17 02 03 Asphalt	0.5	0.5	0.1	4
17 04 01/05 Metals	1-2	2-3	10-15	1-5
Potentially hazardous*	2-10	2-10	0.6	0.2
17 09 04 Mixed C&D waste			5-10	5-10

Table 5 Rounded average percentage of waste composition by volume in rehabilitations (%) [9]

Type of waste	Heavyweight construction: masonry, concrete, etc.	Lightweight construction: precast elements, drywalls, light frame, etc.
15 Packaging waste	35-70	30-70
15 01 01 Paper cardboard pack	1-6	2-4
15 01 02 Plastic packaging	3-8	2-5
15 01 03 Wooden packaging	25-45	20-40
15 01 04 Metallic packaging*	5-15	5-20
15 01 06 Mixed packaging	< 1	< 1
17 C&D waste	25-65	30-70
17 01 01 Concrete	5-10	5-10
17 01 03 Ceramics-bricks	5-15	
17 01 07 Mixed concrete ceramics	10-25	
17 08 02 Drywalls		20-35
17 09 04 Mixed C&D waste	5-15	5-25
17 05 Soil and stones	Varies	Varies

*Waste fulfils at least one criterion for danger.

The data provided in Tables 1-5 can be useful for waste planning and management during construction, demolition, and renovation, allowing a more precise estimation of resources and more efficient waste management.

4. CONSTRUCTION WASTE RECYCLING

As a consequence of intensified construction in Serbia, large quantities of construction waste are generated through activities such as demolition, construction, renovation, adaptation, and other technical maintenance. The increase in these activities has not been matched by the necessary infrastructure for the reception and disposal of construction waste, leading to issues in managing this type of waste and often resulting in illegal dumping at inadequate locations. Handling this waste stream requires a specific approach. The practice of uncontrolled dumping of C&D waste should be abolished as soon as possible. Owners of construction waste should be responsible for the costs of C&D waste management and are required to ensure separate collection and temporary storage.

Currently, there is no practice of separate collection of C&D waste, nor is there a recycling scheme for this type of waste. Construction waste has a very high potential for recycling and is recognized at the European level as a priority waste stream.

Although there is a general legal obligation for the waste producer to collect the generated waste separately and sort it according to future treatment processes in the amount, i.e., percentage, according to the national goals (Article 26 of the Law on Waste Management), this provision does not apply to C&D waste. Typically, only high-value recyclable waste, such as metal, is recycled, while other potentially recyclable materials are disposed of in landfills or, more often, at unsecured local dumpsites.

The following are the main obstacles to recycling construction and demolition waste:

- Legal uncertainty regarding the status of recycled C&D waste (there are still no regulations on the cessation of waste status except for glass, iron and steel, copper, and aluminum).
- Lack of thorough records of sources, quantities, and flows of construction waste, despite the existence of a legal framework, which is not enforced.
- Extremely large quantities of construction waste.
- Uncontrolled disposal of large quantities of construction waste.
- Absence of a system for separating construction waste at the source.
- No separation of hazardous construction waste.
- Lack of incentives for using recycled construction materials.
- No legal obligation for the waste producer to recycle this type of waste (even though the Law on Waste Management defines C&D waste as a priority waste stream for recycling).
- Lack of economic incentives, as mineral C&D waste can be disposed of at a relatively low cost.
- Lack of quality standards for recycled C&D waste (especially in terms of environmental performance), causing liability issues.
- The issue of construction waste is often neglected during the design phase of projects and is not sufficiently regulated by by-laws.
- Absence of a quality market for construction waste.
- Lack of effective communication between all participants in the construction waste management process [10].

5. CONCLUSION

At the end of a building's life cycle, the generated waste will predominantly depend on its type (residential, industrial), the deconstruction criteria adopted in the project (e.g., dry anchoring systems), construction procedures, and materials used in the building's construction (concrete, wood, or metal structure), and the demolition techniques that were used (selective dismantling versus traditional demolition). During the construction and adaptation of buildings, the types and amounts of waste generated on-site depend on the project type, the characteristics of the materials used, and the construction techniques employed.

The investor/contractor is required to handle construction and demolition waste in accordance with the Law on Waste Management and the Regulation on the Manner and Procedure for Construction and Demolition Waste Management, to possess the necessary documentation, to establish separate collection and temporary storage of the waste generated at the construction site, as well as to separate hazardous from non-hazardous construction and demolition waste on-site.

The reuse of waste material and recycling of construction waste has enormous potential because, in addition to saving resources and raw materials, it also allows for additional savings in terms of material costs, transport, and machinery.

To establish a successful and efficient waste management system, it is necessary to do the following: keep a record of the quantities of construction and demolition waste, which needs to be constantly updated; regularly update the Construction Site Register (biannually); establish a system for separating construction and demolition waste on-site; ensure separation of construction and demolition waste on-site by components to provide high-quality recycling material; ensure separation of hazardous construction and demolition waste on-site; build the necessary infrastructure for construction and demolition waste management (build recycling yards and transfer stations, set up mobile plants for the treatment of such waste); utilize construction and demolition waste (use excavated soil to backfill and level the terrain and devastated locations, recycle non-hazardous construction and demolition waste in the recycling yard); and improve inspection and supervision in order to control construction and demolition waste disposal at inadequate locations.

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GRAĐEVINSKI OTPAD OD GRAĐENJA, RUŠENJA I REKONSTRUKCIJE

Povećana izgradnja i rušenje objekata usloville su porast građevinskog otpada od građenja i rušenja. Građevinski otpad se generiše prilikom izgradnje, adaptacije i rušenja otpada. Njegove količine zavise od upotrebljenih materijala, tehnike građenja i vrste projekata. U Republici Srbiji, upravljanje ovim otpadom regulisano je određenom zakonskom regulativom. U radu je data klasifikacija građevinskog otpada prema evropskom katalogu otpada, njegovo nastajanje, upravljanje ovim otpadom, mogućnosti procene otpada pre početka građevinskih radova. Takođe je opisana mogućnost i glavne prepreke reciklaže ovog otpada.

Ključne reči: građevinski otpad (od gradnje i rušenja), plan upravljanja građevinskim otpadom, procena količine građevinskog otpada, reciklaža građevinskog otpada.