Contemporary methods and trends in construction waste management

Author: Ralitsa Kusheva

Abstract: Sustainability is a term which has acquired a key role and importance in various industries, and the construction and demolition waste sector does not remain excluded from these discussions. Sustainable construction and demolition waste management requires that good practices be incorporated and followed, from foundational waste management principles and hierarchies to more vanguard digital solutions, where possible. This article makes an overview of the contemporary methods and trends in construction waste management and summarizes the most efficient ones, which result in reusable building materials, looking at them from the angle of cost-benefit ratio and applicability in the construction landscape in Bulgaria, where good practices are still only partially adopted.

Keywords: construction and demolition; waste management; contemporary methods; good practices; sustainability

JEL: Y4

1. Introduction

The definition of "waste" depends on the context and on the breadth that the relevant analyst wishes to give to the term, but in general it can be explained as "any activity that consumes resources but does not bring any value to the user". Responsible waste management is an essential aspect of sustainable construction. In this context, waste management includes waste prevention where possible; minimizing waste where possible; and reuse of materials that might otherwise become waste. Solid waste management practices identify waste reduction, recycling and reuse as essential to sustainable resource management. As a member state of the European Union, Bulgaria is already involved in international discussions regarding the so-called circular economy, a concept that is increasing in popularity among the other member states of the union. In the context of the current understanding of what circular economy is, sectors such as construction, which require the use of a huge amount of resources and materials and therefore the generation of a significant amount of waste, are among the most directly affected if this concept comes into practical application at the national level.

2. Foundational methods and principles

The remanufacturing of materials generated from construction waste includes "all activities of recovery of construction waste except incineration with energy recovery and processing into materials that are used as fuel" and may also include "activities of preparation for re-use use, recycling or other material recovery" (Waste management law, Bulgaria, 2012).

The most common practices for construction and demolition waste (CDW) management comprise of the so called 3R's principle, derived from the waste management hierarchy. Those refer to the actions of reducing, reusing and recycling, ordered from top to bottom, the one on top being the most desirable, and reciprocally the one at the bottom – the least desirable. Reducing is considered to be the most desirable option for waste management in general, as it effectively prevents waste from being generated, directly resulting in minimized cost. Following the hierarchy, reusing is chosen whenever reduction cannot occur, implying that the same material is used again, either with the same purpose or a different one. Finally, recycling is applied whenever the first two cannot be pursued. It is the least favorable option, as it often bears more cost and has more negative environmental impact.

For CDW management, the polluter pays principle is adopted, on the basis of which it is assumed that those persons who pollute the environment through the creation, contribution and/or possession of waste are obliged to cover all costs of waste management in a manner, which does not further endanger or harm the environment and society. In particular, for construction waste, the contractor of construction waste / construction removal is obliged to finance and manage in full the correct and legal treatment of CDW.

At the same time, Regulation 305/2011 on construction products sets as the 7th basic requirement for construction "sustainable use of resources", providing for "the creation of harmonized standards for construction products and regulating the obtaining of European technical approvals". Based on the principle of "sustainable development", a large part of the construction waste treatment process should focus more on its recovery, in other words, recycling and reusing in future projects, than its landfilling. In this way, not only the well-being of the environment and society is optimized, but also economic development and the smart use of natural resources.

Another one of the fundamental principles concerning the management of CDW is the principle of "best available techniques not entailing excessive costs" (BATNEEC). According to this principle, a critical approach should be taken towards the evaluation of different alternatives in making CDW management decisions that protect both the environment and can be applied in practice at a reasonable cost. In this case, the waste management hierarchy represents a convenient method for carrying out this comparative analysis to assess the different alternatives.

Fig.1 Waste management hierarchy

Source: https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

In the business sector, the BATNEEC principle comes closest to the so-called cost-benefit analysis, on which the author of the present study has based in their dissertation thesis the evaluation of a proposed developed model of an electronic system for optimization CDW management process.

3. Cost-benefit analysis

Before proceeding to the specific results for this analytical scale, the main factors influencing the selection of the main CDW management actions will be discussed in a short tabular format, i.e., disassembly (for demolition or repair), preparation for re-use, recycling, and disposal. Of course, choosing one of these methods does not automatically exclude the use of some of the others, e.g. part of the waste can be landfilled and another part can be recycled if there are adequate resources and those responsible for the process are willing to do so, or part of the building can be carefully disassembled in order to salvage and reuse a larger part of the remaining materials, and the rest to be destroyed and the waste - landfilled.

With this comparative aim, the following table (Tab. 1) presents an analysis between different types of CDW management practices, highlighting the advantages and disadvantages of each solution in terms of these main criteria:

- Costs (of a financial nature, during the implementation of the procedure, but in some situations also during the subsequent stages, such as the sale of residual CDW);
- Time (for performing the procedure).
- Quality of implementation/results (ratio between the two variables, with the quality of implementation also determining the percentage share of results, i.e. of CDW that can be reused or from which additional value can be extracted);

- Safety (of labor on the construction site itself, as well as in related processes such as the transportation of CDW, its disposal or its subsequent processing/development);
- Risk (both for the natural persons on the construction site and for the natural or legal parties who are parties to the construction contract);
- Implementation of the relevant procedure in relation to the contractual conditions (or the need for change/addition to the existing contractual frameworks and standards);
- Opportunities (regarding personnel training and qualifications, especially those employed on the construction site itself).

Tab.1 Comparison table of construction waste management methods

	Preparing for reuse	**Recycling**	**Disassembly**	**Destruction/Disposal**
Costs	Possibility to lower costs with proper reuse	Generally high, but significantly lower if the recycling infrastructure is in place	High due to labor, but this can be offset by selling the salvaged materials	Initially low, but increasing due to landfill charges
Time	Relatively slower process compared to demolition and recycling	Depends on the recycling location (onsite or offsite)	Slow process due to manual deconstruction	Fastest method
Quality of implementation/results	Up to 85% less disposed materials); faster restoration of the site surface	Up to 70% less disposed material	Up to 90% less disposed materials; but the site may be left in a chaotic and untidy state	No waste, but transferred to landfills
Safety	More safety measures are needed because of many additional tasks for workers	More safety measures are needed because of many additional tasks for workers	More safety measures are needed because of many additional tasks for workers	Compliance with existing regulations is required
Risk	The client bears most of the risk and costs; possible environmental risks	Risks related to the timely fulfillment of the contractual terms; possible environmental risks	Potential risks to worker safety, resulting in liability for damages and payment of penalties; possible risks related to unforeseen circumstances	Easy to manage cost, time and environmental risks, but not so easy for contractual risks
Implementation	The contract does not include special information about the recovery of the materials; additional documentation is required for the offer	A recycling promotion clause is often added to a standard contract	Either an entirely new and independent process for the submission of deconstruction proposals/projects is drawn up, or participants are required to submit deconstruction bids in addition to their standard bids/proposals	Standard process regarding invitation to submit proposals/tenders; standard contract clauses
Opportunities	Potential to train staff on how to recover and use	There is no possibility of additional training,	Great potential for staff training, even if they are not sufficiently qualified	There is no possibility of additional

	materials	already qualified personnel are appointed	before	training, already qualified personnel are appointed

Source: An Introduction to Recycling Construction and Demolition Waste

At this stage, most European countries trying to optimize the process of CDW management in their territory tend towards recycling as a middle and sometimes compromise option. In other words, this option provides relatively profitable benefits, and the costs at this stage are relatively manageable and normalized for most participants in the construction process, although in the long term, disassembly, if optimized, and even relatively automated, would lead to significantly more -great benefits for a wider range of stakeholders – not only could construction companies offset their financial investments and costs by selling salvaged building materials, but this option also results in the lowest percentage of disposed waste, which in turn reduces the effect on the environment and indirectly on the welfare of society as a whole.

Despite this focus on recycling, a number of problems facing the simpler and more comprehensive introduction of this practice still remain unresolved in these countries, and these issues are also relevant for the Bulgarian context. For example, empirical studies indicate that the benefits of the CDW recycling process mainly depend on the transport conditions and not so much on the factors of time, personnel qualification, contractual conditions or even risk. In other words, if CDW has to be transported over long distances, then the recycling option is not the most economically efficient from a private sector perspective. At the same time, in countries for which the environmental factor is the driving force, long-distance transportation of CDW is also not profitable, because it contributes to the release of even more CO2 emissions. Also, in some situations a country may have a functioning processing and/or recycling facility for a certain type of material (e.g. bricks) but lack facilities for another base material (e.g. concrete). Even if such a facility existed relatively close in a neighboring country, for example, the costs associated with time and finance, as well as the need to comply with additional regulations and licensing when crossing the border and transporting the materials to another country, would discourage the participants in the process, who would most likely settle on an alternative method of dealing with the waste.

4. Frequently recycled materials

The possibilities for processing and recycling construction materials are presented in the table below (Tab. 2), which shows the large number of alternatives and possibilities for recycling the most commonly used construction materials, as well as the types of products that can be obtained as a result of the application of recycling technologies:

Tab.2 Classification of types of CDW suitable for recycling, methods for achieving this recycling and possible end products

Type of CDW	**Recycling technologies**	**Recycled product**
Asphalt	- Cold recycling - Heat generation	- Recycled asphalt - Asphalt aggregate

	- The Minnesota Process - Parallel drum process - Elongated drum - Microwave asphalt recycling system - Finfalt - Surface regeneration	
Bricks	- Burning to ashes - Crushing to aggregate	- Slime burnt ash - Filling material - Hardcore
Concrete	- Crushing to aggregate	- Recycled aggregate - Cement substitute - Protection of levee - Backfilling - Filler
Ferrous metals	- Melting - Direct use/reuse	- Recycled steel scrap
Glass	- Direct use/reuse - Grind to powder - Polishing - Crushing to aggregate - Burning to ashes	- Recycled window unit - Glass fibers - Filling material - Tile - Paving block - Asphalt - Recycled aggregate - Cement substitute - Artificial soil
Masonry	- Crushing to aggregate - Heating up to 900 °C to ash	- Thermal insulation panel - Traditional clay brick - Sodium silicate brick
Non-ferrous metals	- Melting	- Recycled metal
Paper and cardboard	- Purification	- Recycled paper
Plastic	- Convert to powder by cryogenic milling - Clipping - Crushing to aggregate - Burning to ashes	- Panel - Recycled plastic - Plastic lumber - Recycled aggregate - Landfill drainage - Asphalt - Artificial soil
Timber	- Direct use/reuse - Cut into aggregate - Blast furnace deoxidization - Gasification or pyrolysis - Chipping - Molding by pressurizing timber chip under steam and water	- Whole timber - Furniture and kitchen utensils - Lightweight recycled aggregate - A source of energy - Chemical production - Panel on a wooden base - Plastic lumber - Geofiber - Insulation board

Source: Re-Use of Construction and Demolition Waste in Housing Developments. Nova Publishers Inc., New York, NY, 2008

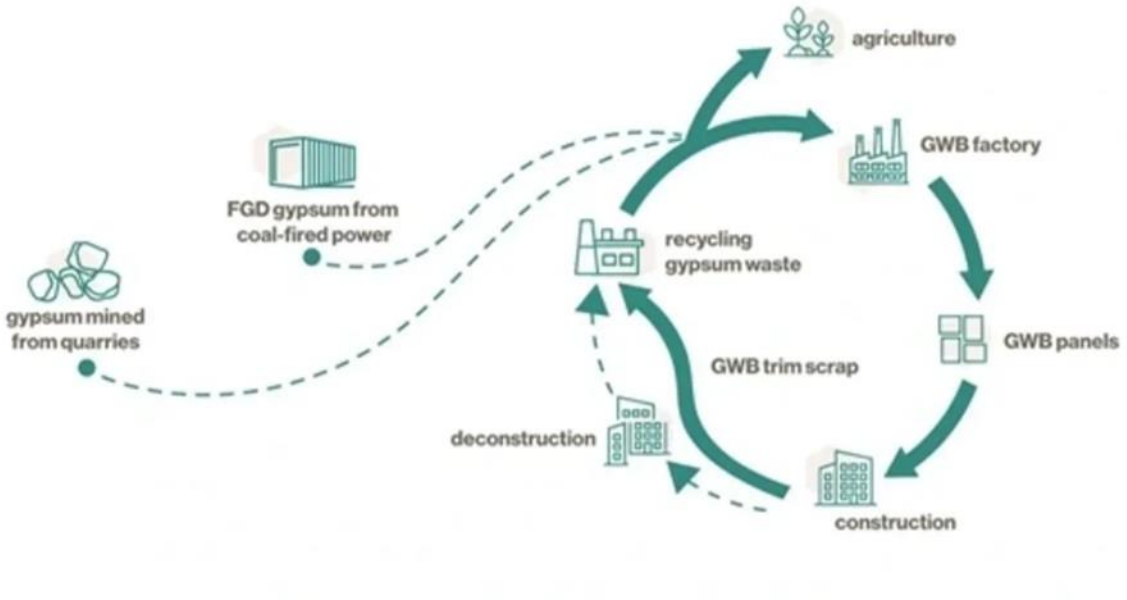
From a rational point of view, Bulgaria is following the steps of more developed European countries, and at this stage most recycled materials on the territory of the country include those that are easier to process and for which it is expected that there will be sufficient market demand, to justify the costs of the recycling process. In comparison, in Europe there is already a wide variety of types of materials processed from construction waste, as well as numerous high-tech facilities and installations that aim at the increasingly optimized and cost-effective utilization of this waste. This development process is guided both by the concepts underlying the circular economy and sustainable practices, and by market principles such as reducing costs but maintaining the quality of the materials used and reducing the number of illegal landfills and discarded waste that could be reused.

Another issue often cited as significant by practitioners in the sector concerns the lack of mobile installations to carry out the recycling unlike in countries such as Switzerland and France where sites exist but the installations for crushing the materials are mobile rather than fixed . The system in these countries works according to the following model – when a sufficient amount of waste is collected at the site of a given municipality, a mobile installation arrives and recycles the specified types of waste on site, thus the recycled CDW can be directly reused. Of course, there are also stationary installations, especially for larger municipalities and sites, where larger and frequent collection of significant amounts of construction waste is expected. For comparison, although in Bulgaria the use of recycled CDW becomes mandatory for certain types of projects, in the words of Eng. Stefan Kinarev from KIIP (Chamber of Engineers in the Investment Design): „Now in our country, even if it is included in the construction project, which is mandatory, it is not known whether the planned quantities will be found quickly, and not after a month with a construction season of 4-5 months. And it is necessary to go to the nearest quarry and take a new one". Also, according to his words, in Bulgaria no washing installations have been made or purchased, which are needed specifically for the crushing of concrete, when a large amount of dust is formed. Thus, despite the stated desire of some companies to use recycled CDW or to offer the remaining materials to recyclers, due to the lack of a sufficiently effective technological base, the working recycling system in Western European countries cannot yet be fully implemented in Bulgaria.

Regarding the recycling of concrete, which is the most commonly reused material worldwide, the results of empirical studies indicate that despite builders' concerns about the durability and quality of recycled concrete compared to new, the difference between the two categories can be attributed to these three main factors: the water-cement (w/c) ratio, the quality of the original concrete from which the recycled is made, and the presence of impurities in the final product. That is, if in the production of recycled concrete these three factors are monitored in order to increase the qualities of the resulting concrete, there is no difference in the long term between the application of a new or recycled concrete product. According to the attitudes in the Bulgarian construction sector, it seems that the lack of mobile installations and the geographical fragmentation of working stationary ones discourage construction companies from buying recycled CDW or selling CDW and handing it over for recycling.

A more detailed waste hierarchy can be seen in the graph in Fig. 2, which represents the reusability of gypsum, as this material is also infinitely recyclable, unlike many other materials that lose their structure or other important qualities in repeated cycles of recycling, reuse, destruction, disassembly, etc. In this way, a closed cycle of creation and recycling of materials such as gypsum can be obtained, which is constantly converted on the basis of waste gypsum. This closed loop is also a significant part of the circular economy concept that the EU has been trying to promote recently, which aims to minimize the amount of waste that ends up in landfills and/or unnecessarily pollutes the environment, when in practice there are real and proven options for extracting additional benefits from them. But for the moment there is a lack of adequate information on the reuse and recycling of gypsum for Bulgaria, despite the proven benefits of this process.

Fig.1 Gypsum waste cycle



Source: https://gypsum2gypsum.com/

5. Final remarks

Innovative phenomena and concepts such as "circular economy", "sustainable development" and "eco-sustainable philosophy/practices" stand out in the foreground in the global and in particular the Western European construction sector. The application of these concepts in practice is increasingly advocated by currently non-binding European protocols and plans, but it is expected in the near future to move to a new type of working attitudes and a circular economy/development philosophy, as well as to the implementation of new practices, adhering to the principle of "circularity". More and more industries and private companies are trying to bet on the reuse of residual materials and waste for various purposes, such as putting them into similar products and projects or diverting them to recycling sites and facilities.

One of the main challenges facing the implementation of the circular economy in Europe, and in particular in Bulgaria, remains the need to preserve market principles for competitiveness and cost reduction. Recycling and reuse of construction products becomes possible if they meet certain criteria or occur in certain situations, such as preserving the quality and value of diverted materials and waste and application of these practices according to state and regional plans and directives of individual administrations.

References

1. Bougrain, F., 2017. Impact of Green Public procurement on the market of recycled concrete. Delft, The Netherlands: HISER International Conference.

2. Enkvist, P-A., Klevnäs, P., 2018. The circular economy – a powerful force for climate mitigation. Stockholm, Sweden: Material Economics.

3. EUR-Lex, 2011. Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC Text with EEA relevance. Available at: https://eur-lex.europa.eu/eli/reg/2011/305/oj

4. Forbes, L.H., Ahmed, S.M., 2020. Lean Project Delivery and Integrated Practices in Modern Construction. Abingdon, UK: Routledge.

5. Guyer, J.P., 2014. An Introduction to Recycling Construction and Demolition Waste. Null edition CreateSpace Independent Publishing Platform.

6. Gypsum to Gypsum, 2018. Waste Hierarchy. Available at: https://gypsumtogypsum.org/gtog/waste-hierarchy/ [02.09.2022].

7. Hebel, D.E., Wisniweska, M.H., Heisel, F., 2014. Building from Waste: Recovered Materials in Architecture and Construction. Basel, Switzerland: Birkhäuser.

8. Kostova, K., 2018. Stroitelnite otpadutshi – problem za predpriemachite ili dopulnitelna vuzmozhnost? Available at: http://stroitelstvoimoti.com/%D1%81%D1%82%D1%80%D0%BE%D0%B8%D1%82%D0%B5%D0%BB%D0%BD%D0%B8%D1%82%D0%B5-%D0%BE%D1%82%D0%BF%D0%B0%D0%B4%D1%8A%D1%86%D0%B8-%D0%BF%D1%80%D0%BE%D0%B1%D0%BB%D0%B5%D0%BC-%D0%B7%D0%B0-%D0%BF%D1%80%D0%B5/

9. Pacheco-Torgal, F., Ding, Y., Colangelo, F., Tuladhar, R., Koutamani, A., 2020. Advances in Construction and Demolition Waste Recycling: Management, Processing and Environmental Assessment. Woodhead Publishing, Elsevier.

10. Tam, V.W.Y., Tam, C.M., 2008. Re-Use of Construction and Demolition Waste in Housing Developments. New York, NY: Nova Publishers Inc.

11. Wahlström, M., Bergmans, J., Teittinen, T., Bachér, J., Smeets, A., Paduart, A., 2020. Construction and Demolition Waste: challenges and opportunities in a circular economy", European Environment Agency.