



EJENS

European Journal of Engineering and Natural Sciences



e-ISSN : 2458-8156

Optimal Management of Construction Waste

Dino Obradović^{1*}, Marija Šperac¹

¹ Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, 31000 Osijek, Croatia.

*Corresponding Author email: dobradovic@gfos.hr

Abstract

Construction waste is a key issue of modern society. Construction waste is a type of waste generated during the construction of buildings, reconstruction, demolition and maintenance of the existing buildings, and waste generated from excavated materials which cannot be reused for the construction of new buildings without prior recycling or processing. Moreover, construction waste is generated during the production of semi-finished and finished construction products and materials, as well as during the construction and reconstruction of roads. Large quantities of construction waste are generated by earthquakes, floods and destruction caused by war. Construction waste predominantly (95 %) consists of inert waste which means that it is not subject to physical, chemical or biological changes, that it does not dissolve or chemically react, is not flammable, and is not degradable using biodegradable means. Some types of inert construction waste are ceramics, plaster, gypsum, concrete, iron, steel, waste from demolition of buildings, wood, plastics, etc. It may contain hazardous components such as asbestos or asphalt binders, and these components classify it as hazardous waste. Construction waste can generally be divided into three broad categories, such as construction material, demolition waste and hazardous waste. We generate less waste by construction than by demolition. Construction and demolition waste account for the largest percentage of total waste in the European Union – in terms of its volume, it accounts for almost one-third of all waste. For the purpose of achieving the optimal management of construction waste, the following hierarchical approach must be followed: prevention of waste, preparation for reuse, recycling, other treatment procedures, waste disposal. It is necessary to develop a circular economy covering the cycle from construction to demolition to new construction that uses recycled waste materials. Using the available modern technologies, it is possible to reuse most of the construction waste as secondary raw material. The optimal management of construction waste significantly reduces environmental pollution.

Key words

Circular economy, Construction waste, Optimal management, Pollution, Recycling

1. INTRODUCTION

1.1. Issues on Construction Waste

Nowadays, increasing quantities of waste are being generated which create a major problem, as appropriate methods and sites for its disposal need to be found. Moreover, since there is a need to build new buildings and demolish the old, worn-out ones, large quantities of construction waste are also generated. Generally speaking, waste is becoming a key problem of modern civilisation and the inevitable consequence of man's life. The

priority should be to reduce environmental pollution and the production of all types of waste, including construction waste. In order to address the problems posed by construction waste, it is necessary to manage it properly. Today, modern technologies allow most waste, including construction waste, to be used as secondary raw material. Proper treatment and management of different types of waste is important. Construction waste is also an important type of waste generated in large quantities.

Construction waste is a type of waste generated during the construction of buildings, reconstruction, demolition and maintenance of the existing buildings, and waste generated from excavated materials which cannot be reused for the construction of new buildings without prior recycling or processing. Moreover, construction waste is generated during the production of semi-finished and finished construction products and materials, as well as during the construction and reconstruction of roads. Also, large quantities of construction waste are generated by earthquakes, floods and destruction caused by war.

In terms of quantity, construction and demolition waste constitute the EU's largest waste stream. It represents approximately one-third of the total waste produced. Proper management of construction and demolition waste and waste obtained from recycled materials, including proper handling of hazardous waste, can significantly contribute to sustainability and quality of life. However, the EU construction and recycling industry can also benefit greatly from this as the demand for recycled materials from construction and demolition waste is increasing. However, one of the common obstacles to recycling and reuse of construction and demolition waste in the EU is the lack of confidence in the quality of recycled materials from construction and demolition waste. In addition to this, there is uncertainty as to the potential risk to the health of workers using recycled materials from construction and demolition waste. The lack of trust reduces and limits the demand for recycled materials from construction and demolition waste, thus preventing the development of the infrastructure necessary for the management and recycling of construction and demolition waste in the EU [1].

1.2. Types of Construction Waste

Some common types of construction waste include:

- Excavation material (soil, stones)
- Insulation and asbestos material
- Concrete and mortar material
- Brick, tiles, ceramics
- Wood materials
- Metallic waste
- Glass, polymers, etc.

Construction and demolition waste grouping are given in Figure 1.

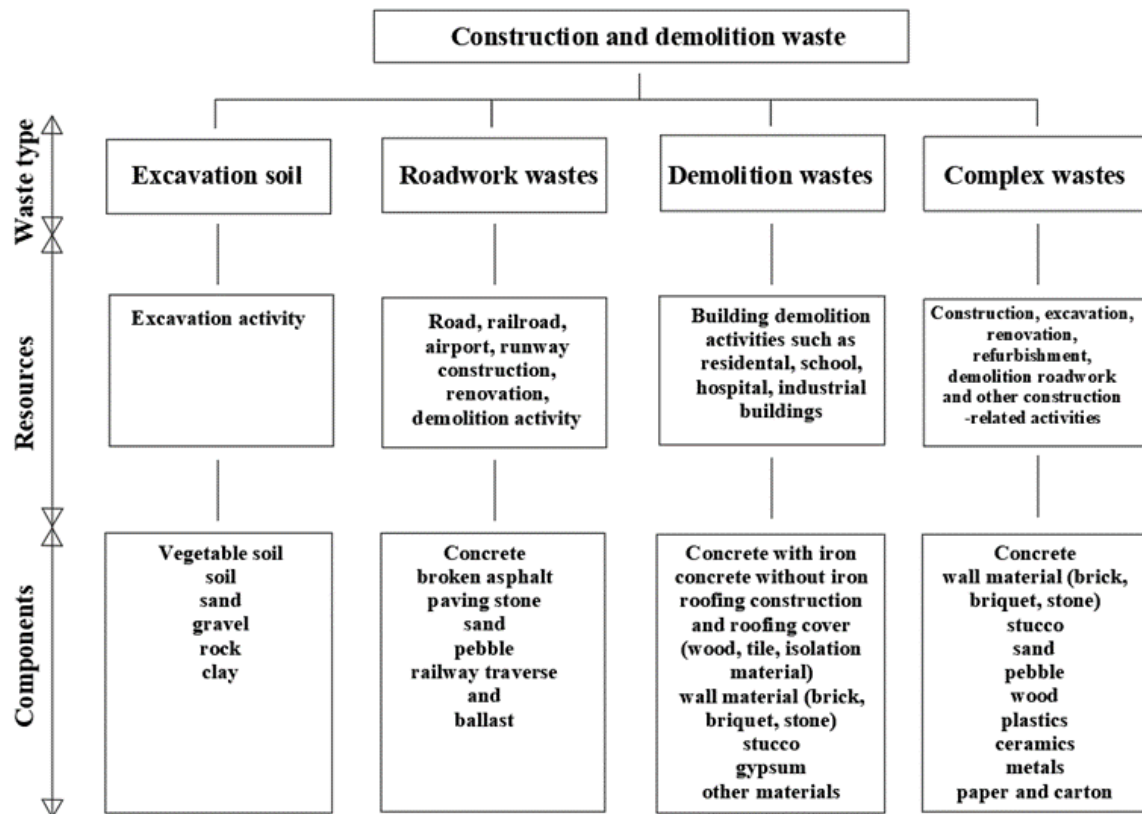


Figure 1. Construction and demolition waste grouping (according to [2])

2. WASTE GENERATION BY ECONOMIC ACTIVITIES AND HOUSEHOLDS

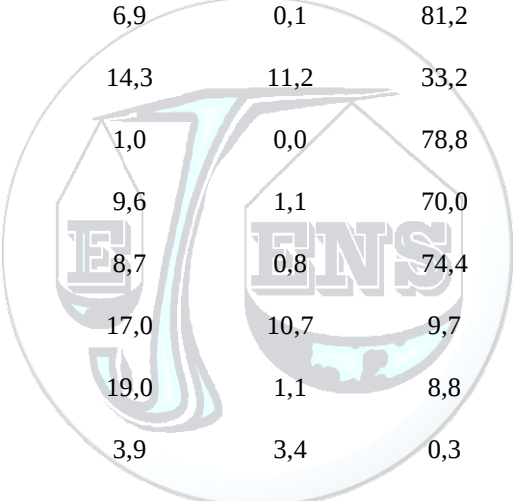
2.1. Waste Generation by Economic Activities and Households

In 2018, the total waste generated in the European Union (EU) by all economic activities and households amounted to 2 337 million tonnes [3].

Table 1. shows waste generation by economic activities and households in 2018 in EU. Data are given in % share of total waste.

Table 1. Waste generation by economic activities and households in EU in year 2018 [3] (% share of total waste)

Country	Types of economic activity					
	Mining and quarring	Manufacturing	Energy	Construction and demolition	Other economic activities	Households
EU	26,6	10,6	3,4	35,9	15,4	8,2
Belgium	0,1	24,9	1,2	33,5	33,1	7,2
Bulgaria	82,4	2,0	10,0	0,1	3,1	2,4
Czechia	0,2	14,6	1,5	41,7	26,7	15,3
Denmark	0,0	4,7	5,1	56,0	17,8	16,4



Germany	2,2	13,9	2,3	55,5	16,8	9,2
Estonia	29,5	18,8	32,3	9,5	7,6	2,4
Ireland	14,2	24,7	1,1	13,6	35,1	11,4
Greece	56,4	11,8	7,6	5,0	9,2	10,1
Spain	17,1	9,9	2,4	27,6	26,5	16,5
France	0,4	6,6	0,4	70,2	13,7	8,7
Croatia	12,0	8,9	1,3	22,7	31,7	23,3
Italy	0,8	16,5	1,3	35,3	28,7	17,5
Cyprus	6,6	16,3	0,1	45,8	14,5	16,8
Latvia	0,1	21,7	2,5	17,5	25,7	32,6
Lithuania	1,6	37,2	2,1	8,8	30,3	20,0
Luxembourg	0,0	6,9	0,1	81,2	9,7	2,1
Hungary	1,0	14,3	11,2	33,2	25,4	14,9
Malta	1,6	1,0	0,0	78,8	11,2	7,4
Netherlands	0,0	9,6	1,1	70,0	13,3	6,0
Austria	0,1	8,7	0,8	74,4	9,3	6,7
Poland	36,7	17,0	10,7	9,7	20,6	5,3
Portugal	0,2	19,0	1,1	8,8	38,1	32,8
Romania	88,0	3,9	3,4	0,3	2,4	2,1
Slovenia	0,2	20,2	11,8	8,1	51,9	7,8
Slovakia	2,2	27,5	7,9	4,4	39,8	18,2
Finland	74,9	6,7	1,0	12,3	3,5	1,6
Sweden	74,7	3,7	1,4	8,9	8,0	3,2
Iceland	0,0	24,4	0,0	3,9	31,5	40,2
Liechtenstein	1,6	1,5	0,0	88,6	1,6	6,7
Norway	1,2	12,8	1,5	40,0	27,4	17,1
United Kingdom	5,2	4,0	0,2	48,8	32,4	9,4
Montenegro	27,4	3,7	27,6	11,3	8,6	21,4
North Macedonia	14,2	46,6	0,5	3,1	35,6	0,0

Serbia	75,6	2,9	14,7	1,1	2,1	3,6
Turkey	17,9	:	26,1	0,0	7,1	28,9
Bosnia and Herzegovina	8,2	28,1	48,1	1,8	0,2	13,6
Kosovo	93,5	2,0	3,4	0,1	0,0	1,0

As can be seen in Table 1, construction and demolition sector account for the largest share of total waste in about half of the total number of countries presented. From the data obtained, it can be concluded that the construction and demolition sector generate large quantities of waste which needs to be properly disposed of.

The share of different economic activities and of households in total waste generation in 2018 is presented in Figure 2. Data are given in % share of total waste.

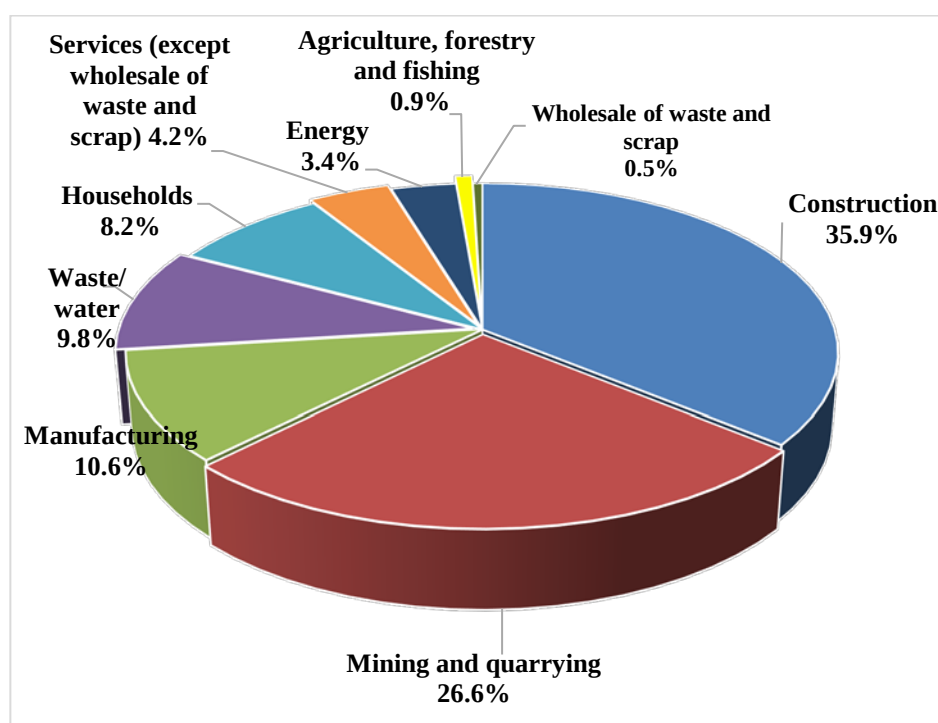


Figure 2. Waste generation by economic activities and households in EU, year 2018 (according to [3])

Presented data on Figure 2 are given in % share of total waste. In the EU, construction contributed 35.9 % of the total in 2018 and was followed by mining and quarrying (26.6 %), manufacturing (10.6 %), waste and water services (9.8 %) and households (8.2 %). The remaining 9.1 % was waste generated from other economic activities, mainly services (4.2 %) and energy (3.4 %) [3]. In overall terms, according to Figure 2, it is the construction sector that generates the largest quantities of waste in the EU, accounting for 35.9 % of the total amount of waste in the EU.

Table 2 shows the development of EU waste generation excluding major mineral waste analysed by economic activity. In 2018, the highest levels of waste generation were recorded for waste and water services (208 million tonnes), for households (186 million tonnes) and for manufacturing activities (180 million tonnes) [3].

As shown in Table 2 for the period from 2004 to 2008, the movement of total waste has taken an ascending trend, as confirmed in Figure 3.

Table 2. Waste generation, excluding major mineral waste in EU from 2004 to 2018 [3] (in million tonnes)

Economic activity	Year							
	2004	2006	2008	2010	2012	2014	2016	2018
Total	779,5	789,9	760,5	758,7	758,0	769,0	784,7	812,0
Agriculture, forestry and fishing	62,3	56,7	45,5	20,2	20,4	17,7	19,7	19,5
Mining and quarrying	10,4	7,1	10,0	7,9	7,5	7,7	6,9	8,1
Manufacturing	239,9	225,8	216,8	190,5	176,4	175,9	178,9	180,1
Energy	85,4	93,3	84,1	78,6	88,8	87,4	74,7	75,7
Waste/water	75,2	83,3	98,9	129,9	155,0	180,7	196,9	207,6
Construction	34,4	33,4	34,8	42,5	39,8	38,6	37,8	41,3
Other sectors	97,7	111,2	88,8	102,3	88,9	85,1	88,5	94,0
Households	174,1	179,2	181,6	186,0	180,7	175,9	181,4	185,7

Figure 3 shows the movement of the total amount of waste in the EU from 2004 to 2018. The trend of increasing the total amount of waste has been observed.

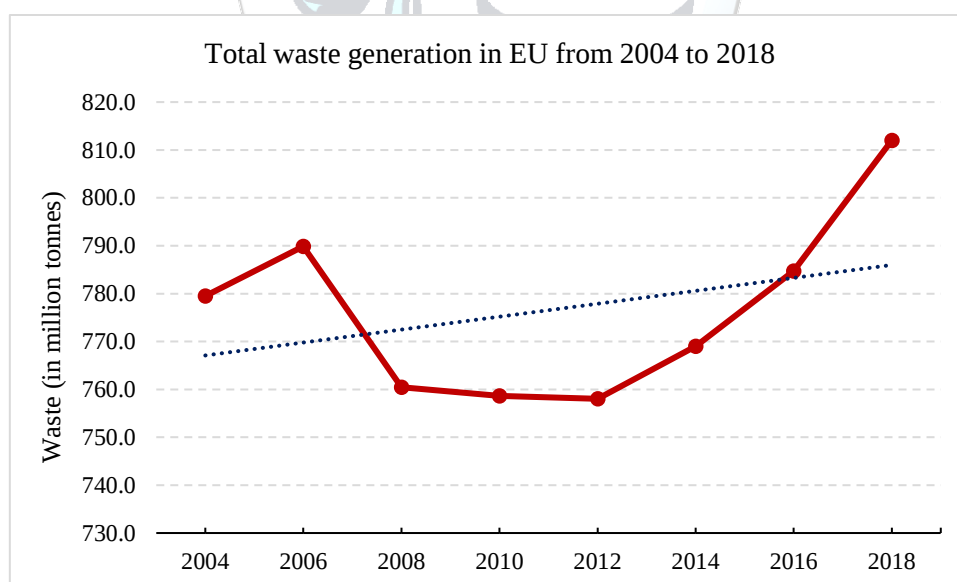


Figure 3. Total waste generation in EU from 2004 to 2018 (author's work according to [3])

2.2. Waste Generation by Construction Sector in EU

The amount of waste generated by the EU construction sector from 2004 to 2018 is on the rise. As shown in Figure 4, an increase in the amount of waste from the construction sector can be observed.

The construction sector in the EU is the highest producer of waste when compared with other economic sectors, accounting for 35 % of the total waste generation. This equates to two and four times more than the total household waste produced in US and Europe respectively [3], [4], [5].

In 2018, the total waste generated in the European Union (EU) by all economic activities and households amounted to 2 337 million tonnes [3].

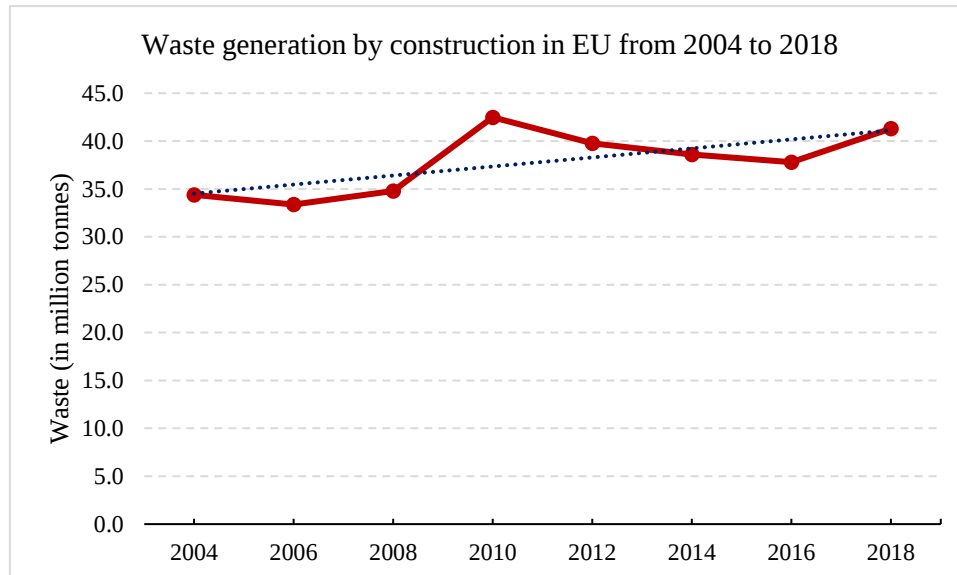


Figure 4. Waste generation by construction activities in EU from 2004 to 2018 (author's work according to [3])

3. CONSTRUCTION WASTE MANAGEMENT

Construction and demolition (C&D) materials (Figure 5) are generated when new building and civil-engineering structures are built and when existing buildings and civil-engineering structures (highways, bridges, utility plants, dams, etc.) are renovated or demolished, including deconstruction activities [6]. A significant amount of industrial waste is created by the construction industry which is generally categorized as construction and demolition waste which has become a concern of governments and consequently, of construction companies [7], [8]. Construction and demolition waste treatment has become an increasingly pressing economic, social, and environmental concern across the world [9]. Construction and demolition wastes threaten many countries because they make up the largest portion of the solid waste stream [10], [11] and construction waste poses a great danger to the environment [12]. Waste management is a crucial part in construction industry [13].



Figure 5. Construction and demolition waste

3.1. Hierarchical Approach and Circular Economy

The construction sector is the biggest driver of resource consumption and waste generation in Europe. The European Union is making efforts to move from its traditional linear resource and waste management system in the construction sector to a level of high circularity [14]. The most recent effort of the European Union resulted in the Circular Economy Action Plan. The first Action Plan that was published in 2015 revolved around the transition from linear to circular economy business models [15], [16].

Circular economy is a strategy used for the transition from the existing linear economy to the circular economy. This is an economic model that provides a sustainable resource management, a longer product lifespan with the aim of reducing waste and an increased use of renewable energy sources. Unlike the linear economy, this is a concept in which the flows of resources and energy are maintained within the closed loop model, aiming to make the products circulate as long as possible within the circular cycle (Figure 6). The emphasis is on the production and design of products that can be easily disassembled, which contain no hazardous substances, have a long lifespan and can be easily repaired [17]. Circular economy is contrary to the concept guided by the principle of, say, “manufacture, consume and discard.” The circular economy model implies a change in the paradigm of the existing management of resources in an efficient and smart way. Such concept is based on eco-innovation, eco-design, advanced technologies, energy efficiency and the use of renewable energy sources. The method of production applied in the linear economy is unsustainable and creates large quantities of waste the disposal of which is based on the mistaken belief that resources are inexhaustible and that the space for waste disposal is unlimited [17].

The 3R approach (Recycle, Reduce and Reuse) is shown in Figure 6 [18].

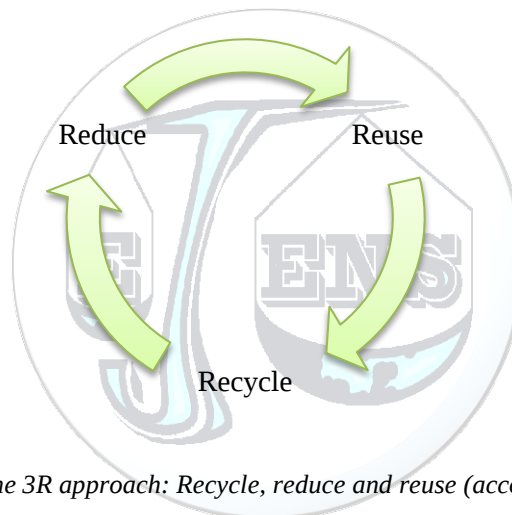


Figure 6. The 3R approach: Recycle, reduce and reuse (according to [18])

The Waste Framework Directive 2008/98/EC [19] lays down some basic waste management principles (Figure 7).

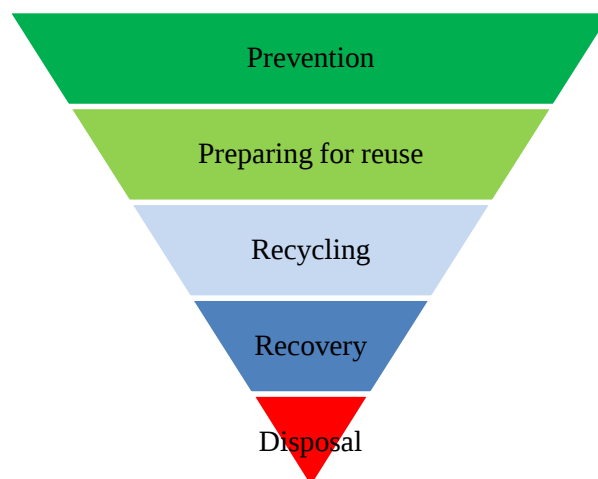


Figure 7. EU waste hierarchy (author's work according to [20])

As presented in Figure 7, which shows the Waste Framework Directive 2008/98/EC, prevention is the most desirable practice, i.e. generation of waste is reduced as much as possible. It is followed by a preparing for reuse, then recycling and recovery. At the very bottom of the hierarchy, there is disposal which is the least desirable way to manage waste.

3.2. Construction Waste Management After Natural Disasters

Natural disasters can generate large quantities of waste that may directly threaten public health (e.g. direct human contact with hazardous waste such as asbestos), impede reconstruction (e.g. block access to affected populations and areas) and impact the environment. In particular, damage to infrastructure and buildings generate a significant amount of construction waste such as bricks, concrete and concrete rubble [21].

This occurs in two phases:

- 1) when the actual natural disaster occurs and
- 2) later during the response and recovery activities [21].

Large amounts of waste debris occur in urbanised areas when heavy rain on local geology generates flooding and landslides [22]. The pre-disaster construction and demolition waste management phase consists of measures to control disaster waste generation such as building regulations and codes. The post disaster construction and demolition waste management phase includes collecting, transporting, processing and disposing of waste generated by disasters, partial demolitions and reconstruction during relief, rehabilitation and reconstruction phase of disaster waste management cycle [23], [24].

Ruined buildings and infrastructure generates a tremendous quantity of debris including rubble, concrete, bricks, steel and timber that places an additional burden on a community. Thus, in rebuilding, the process should encourage incorporation of building waste reduction, reusing and recycling strategies [25].

3.3. Construction Waste Management After War Destruction

The destruction of property and buildings is an inevitable part of military operations. The accumulation of debris in the streets often impedes the processes of rescue, distribution of aid and services, and other forms of city life as well. Also, the amount of effort and energy needed to remove those residual materials to their final dumping sites divert a lot of urgently needed resources [26].

Some of many benefits of construction and demolition debris management are conservation of natural resources, environmental and economic sustainability, the economical utilization of landfills, the reduction of illegal and unauthorized dumping, reduced energy usage, cost recovery and financial incentives and compliance with policies, laws and regulations [25], [27].

4. CONCLUSION

Construction waste is generated during construction of buildings, reconstruction and maintenance of buildings, demolition and removal, and excavation of the building material. Construction waste is one of the major problems of modern times since it is generated in large quantities from the increased construction activities, i.e. urbanization. Moreover, large quantities of construction waste are caused by natural disasters, such as earthquakes, floods, as well as war destruction. Some types of construction waste include: concrete, roof tiles, metal, gypsum, floor tiles, wood, plastics, etc. When looking at the structure of waste in the European Union, it has been observed that construction waste accounts for one-third of the total amount of waste. During the construction of buildings, it is necessary to keep in mind the ways of waste management. The European Union applies the waste prevention and management policy based on the specific waste hierarchy which includes: prevention, preparation for reuse, recycling, and other recovery procedures, such as energy recovery and disposal. A lot of material obtained from construction waste such as concrete, bricks and metal is suitable for recycling and reuse. It is important that waste is separated at the site of its formation which prevents contamination by other substances and thus increases its value. It is also important to develop a circular economy model in which the flow of resources and energy is maintained in the closed loop model, where the products circulate as long as possible within the circular cycle. In the circular economy model, eco-design, advanced technologies, energy efficiency and the use of renewable energy sources stand out, which are applicable in the field of construction. Environmental pollution can be reduced if construction waste is optimally managed.

REFERENCES

- [1]. European Commission. EU Construction & Demolition Waste Management Protocol. 2016.
- [2]. H. Arslan, N. Coşgun and B. Salgın. *Construction and Demolition Waste Management in Turkey*. In Waste Management, L. F. Marmolejo Rebollon (ed.). 2012.
- [3]. Eurostat. Eurostat statistics explained. Waste statistics. April 2021. [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation (Accessed: 17.06.2022).
- [4]. EPA United States Environmental Protection Agency. (2020). Advancing Sustainable Materials Management: 2018 Fact Sheet. [Online]. Available: https://www.epa.gov/sites/default/files/2021-01/documents/2018_ff_fact_sheet_dec_2020_fnl_508.pdf (Accessed: 23.06.2022).
- [5]. P. V. Sáez and M. Osmani. "A diagnosis of construction and demolition waste generation and recovery practice in the European Union", *Journal of Cleaner Production*, vol. 241, 118400, December 2019.
- [6]. EPA United States Environmental Protection Agency. (2021) Sustainable Management of Construction and Demolition Materials. [Online]. Available: <https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials> (Accessed : 22.06.2022).
- [7]. A. Turkyilmaz, M. Guney, F. Karaca, Z. Bagdatkyzy, A. Sandybayeva and G. Sirenova. "A Comprehensive Construction and Demolition Waste Management Model using PESTEL and 3R for Construction Companies Operating in Central Asia", *Sustainability*, vol. 11, no. 6, 1593, March 2019.
- [8]. R. Jin, H. Yuan, and Q. Chen, "Science mapping approach to assisting the review of construction and demolition waste management research published between 2009 and 2018". *Resources, Conservation and Recycling*, 140, pp. 175–188. 2019.
- [9]. N. Elshaboury, A. Al-Sakkaf, E. M. Abdelkader and G. Alfalah. "Construction and Demolition Waste Management Research: A Science Mapping Analysis", *International Journal of Environmental Research and Public Health*. vol. 19, no. 8, 4496, 2022.
- [10]. N. Elshaboury and M. Marzouk, "Optimizing construction and demolition waste transportation for sustainable construction projects", *Engineering, Construction and Architectural Management*, vol. 28, no. 9, pp. 2411-2425., November 2021.
- [11]. S. Elgizawy, S. El-Haggar and K. Nassar, "Approaching sustainability of construction and demolition waste using zero waste concept", *Low Carbon Economy*, vol. 7, no. 1, pp. 1-11, March 2016.
- [12]. E. Lawson. (2020) RECYCLING Magazine. Best Practices for Construction Waste Management. [Online]. Available: <https://www.recycling-magazine.com/2020/03/30/best-practices-for-construction-waste-management/> (Accessed : 24.06.2022).
- [13]. K. Jie Cheng and M. A. Othuman Mydin, Best Practice of Construction Waste Management and Minimization. *ANALELE UNIVERSITĂȚII, "EFTIMIE MURGU" REȘIȚA ANUL XXI, NR. 1*, 2014.
- [14]. C. Zhang, M. Hu, F. Di Maio, B. Sprecher, X. Yang and A. Tukker, „An overview of the waste hierarchy framework for analyzing the circularity in construction and demolition waste management in Europe”. *Science of The Total Environment*, vol. 803, 149892, January 2022.
- [15]. A. Nadazdi, Z. Naunovic and N. Ivanisevic. "Circular Economy in Construction and Demolition Waste Management in the Western Balkans: A Sustainability Assessment Framework". *Sustainability*, vol. 14, 871. pp. 1-17, January 2022.
- [16]. European Commission. Closing the Loop-An EU Action Plan for the Circular Economy, COM (2015). Brussels, 2015. [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614> (Accessed 5.11.2021.).
- [17]. RA IGRA. Što je cirkularna (kružna) ekonomija?. [Online]. Available: <http://www.ra-igra.hr/sto-je-cirkularna-kruzna-ekonomija/> (Accessed: 20.06.2022).
- [18]. P. Morganti. "Bionanotechnologies & Goods for a Greener Planet". *Sofwjournal*. vol 10, no. 15 pp. 52-56. 2015.
- [19]. European Commission, EUR-Lex. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705> (Accessed: 23.06.2022).
- [20]. European Commission, EUR-Lex. Waste Framework Directive. [Online]. Available: https://environment.ec.europa.eu/sites/default/files/styles/oe_theme_medium_no_crop/public/2021-01/SC656%20waste_hierarchy%20FINAL.jpg?itok=fTGHo3-Y (Accessed: 20.06.2022).
- [21]. S. Shooshtarian, T. Maqsood, P. Wong, M. Khalfan and R. Yang. "Construction Waste Management in Natural Disasters in Australia". *Global Journal of Engineering Sciences*. vol. 3, no. 5. 2019.
- [22]. A. Amato, F. Gabrielli, F. Spinozzi, L. M. Galluzzi, S. Balducci and F. Beolchini, "Disaster waste management after flood events", *Journal of Flood Risk Management*, vol. 13, no. supplement 1, pp. 1-9, September 2019.

- [23]. G. Karunasena and D. Amaratunga, "Capacity building for post disaster construction and demolition waste management: A case of Sri Lanka", *Disaster Prevention and Management*, vol. 25, no. 2, pp. 137-153. April 2016.
- [24]. G. Karunasena, D. Amaratunga, R. Haigh and I. Lill, "Post disaster waste management strategies in developing countries: case of Sri Lanka", *International Journal of Strategic Property Management*, vol. 13, no. 2, pp. 171-190. April 2009.
- [25]. G. Karunasena, D. Amaratunga and R. Haigh. „Post-disaster construction & demolition debris management: A Sri Lanka case study“, *Journal of Civil Engineering and Management*. vol. 18, no. 4. pp. 457-468. 2012.
- [26]. H. Al-Qaraghuli, Y. Alsayed and A. Almoghazy. "Postwar City: Importance of Recycling Construction and Demolition Waste". *IOP Conference Series: Materials Science and Engineering*. vol. 245. 082062, pp. 1-8, 2017.
- [27]. R. Raufdeen, *Construction Waste Management: Current status and challenges in Sri Lanka*. Galle: COWAM centre. 80 p, 2009.

