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Circular economy implemented on the construction site

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Abstract: Construction is a branch of the economy that occupies a leading place in waste production. The problem concerns both the demolition of buildings at the end of their lifespan and the construction process itself. During the demolition process, waste is segregated, and most often concrete and brick rubble, wooden and wood-based elements, and metal and glass are recycled. However, there is still a large amount of mixed waste, which often contains hazardous waste. It is necessary to store this waste safely. Another problem is waste generated during construction. The largest percentage of which is packaging. In construction practice, the waste is most often transported to companies that deal with its segregation and partial processing as mixed waste. However, in the idea of a closed-loop economy, in addition to waste processing, there is an attempt to reduce the negative impact on the environment which may be caused by, among other factors, the transport of this waste. The article proposes the possibility of using some packaging waste directly on the construction site. In the article, the authors proposed a practical solution to manage a significant part of the waste generated during construction. This solution provides a place for the production of elements needed to develop the area around the building using technology based on secondary raw materials. This approach allows for the implementation of the green building philosophy in a more complete form.

Keywords: circular economy, construction waste, green building

Please, quote this article as follows:

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Introduction

The development of any branch of the economy is inextricably linked to the generation of waste, and the construction industry is one of the biggest producers of this type of environmental hazard (Benachio et al., 2020). A large amount of waste is generated during construction work as well as during other stages of a building's

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life cycle, and this waste needs to be handled. Over 30 % of waste generated in the European Union, which corresponds to 800 tons of waste annually, originates from the construction sector 2 (Szafranko & Jurczak, 2023). This is a global issue, which motivates the European Parliament to take measures in order to reduce the creation of waste and to maximise its recycling (Szafranko & Harasymiuk, 2017; Szafranko, 2017). Numerous regulations and directives issued by the European Union contain many suggestions and recommendations aimed at improving the situation, e.g. companies are recommended to draw attention to the efficient use of resources, or to support initiatives undertaken to improve the use of the waste they generate (Directive 2008/98/EC; EU COM 2024).

Construction waste management should be based on the hierarchy of activities in compliance with the applicable regulations. First and foremost, a construction process should be planned and conducted so as to reduce the amount of waste generated. The waste that is nevertheless generated should be prepared for reuse, and it is best to consider the possibility of waste processing at the site from which it originates. Further recommended actions include recycling, other recovery technologies and, finally, waste disposal (Ginga et al., 2020). Reusing and recycling construction waste opens up many opportunities for creative building design and construction. Circular architecture, which aims to produce designs of buildings in accordance with the principles of the circular economy, is an example of such innovative solutions (Papastamoulis et al., 2021; Wahi et al., 2016). According to circular architecture, it is recommended to design buildings which involve the use of recycled materials, and which are shaped in a way that will make it possible to recover some component parts of these buildings in the future, at the time of demolition (Pietrzak, 2019; Poon et al., 2004). Figure 1 shows a linear model of a construction approach considered traditional, whereas Figure 2 illustrates the circular model.

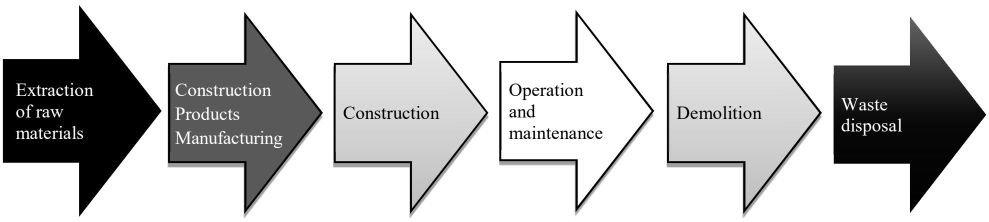

Fig. 1. Linear model of construction (*own research*)

In order to implement waste management principles, it is necessary to ensure that different types of waste are properly sorted out on site (Directive 2008/98/EC; EU COM 2024). For this purpose, among other aims, a catalogue of waste has been developed, and construction waste was included in Chapter 17 – waste from construction, renovation and demolition of buildings and road infrastructure, including excavated soil from contaminated areas. The catalogue is divided into chapters and subchapters, as demonstrated in Table 1.

Apart from the construction waste listed in Chapter 17, any construction project also generates large volumes of packaging waste. These are classified in Chapter 15 subchapter 01, and comprise of packaging from paper, cardboard, plastics, wood, metal, glass, textiles, mixed and contaminated. All kinds of waste mentioned above appear at a construction site.

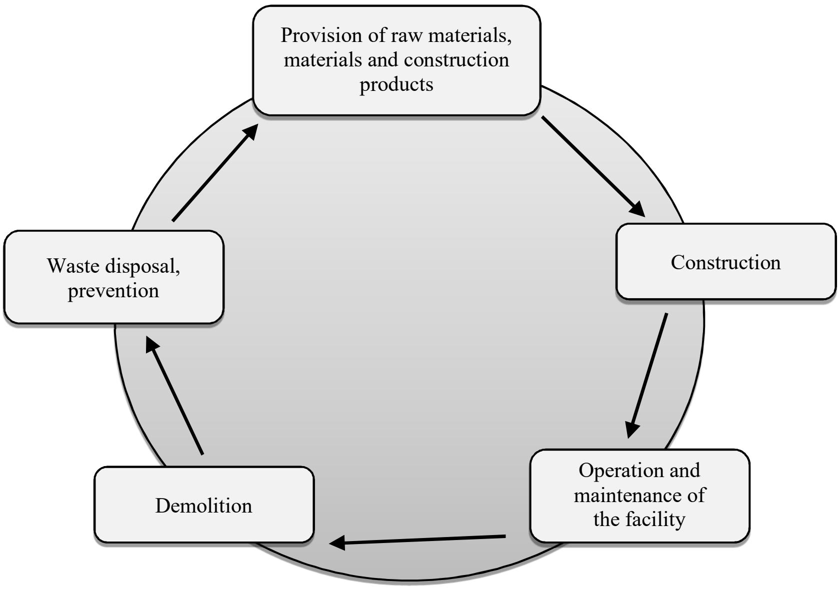

Fig. 2. Circular model of construction (*own research*)

Table 1. The catalogue of the waste from construction, renovation and demolition of buildings and road infrastructure (author based on Directive 2008/98/EC; EU COM 2024)

Code	Chapters, subchapters
17	Waste from construction, renovation and demolition of buildings and road infrastructure (including excavated soil from contaminated areas)
17 01	Waste from building materials, elements and road infrastructure (e.g. concrete, bricks, tiles, ceramics)
17 02	Wood, glass and plastic waste
17 03	Bituminous mixtures, coal tar and tarred products
17 04	Metallic and metal alloy waste and scrap
17 05	Soil and stones (including soil and stones from contaminated areas and dredging spoil)
17 06	Insulation materials and construction materials containing asbestos
17 08	Gypsum-based construction materials
17 09	Other mixed construction and demolition waste

In line with the circular economy, the right approach to waste primarily ensures closing of the loop in accordance with a circular scheme that brings together the launching of building works and the termination of a building's useful life and its demolition (Menegaki & Damigos, 2018; Mahpour, 2018; Schützenhofer et al., 2022). When designing buildings in compliance with the green building philosophy, architects and constructors are recommended to take into account elements which will be submitted to reusing when the building is torn down, or recycled. However, they are also advised to design a building in a way that will maximise the amount of construction materials and elements that will be reused (Diemer et al., 2022; Musarat et al., 2022; Ruiz et al., 2020). The waste generated during construction and associated processes are mentioned far less frequently. However, a considerable amount of waste must be dealt with at this stage. Construction of a typical single-family house generates about 10 tons of waste. When larger buildings are raised, this amount will increase significantly. Disposal of construction waste from a building site generates additional economic, social and environmental costs (Nadazdi et al., 2022). In a costs-breakdown of a construction project, the contribution of costs incurred by the disposal of waste can be up to 10 % of the total costs related to the development. The exact percentage of these costs in total costs depends on the character of construction works and technologies employed, as well as the size of a development. The social and environmental costs are mostly due to the need to transport large amounts of waste, often over long distances. In view of the above considerations, the author of this article decided to review a solution which would facilitate the handling of the largest possible mass of waste on a construction site so as to reduce the costs of transport and, above all, the environmental costs thereof (Directive 2008/98/EC; Joensuu et al., 2020; Soto-Paz et al., 2023). The aim of the study is to develop a proposal for the use of waste at the place of its generation, i.e. on the construction site.

1. Materials and methods

The research begins with a review of the relevant literature and an analysis of source materials and information (stage 1 in the diagram). The materials and data submitted to the study were collected during site visits and seminars held for construction contractors. Data pertaining to quantities and structure of waste as well as distances over which waste had to be transported were summarised. This enabled the authors to define the research problem: "the need to reduce the size of the waste stream transported from the construction site by developing a waste segregation process for on-site use".

The subsequent stage aimed to identify benefits achieved from limiting amounts of waste removed from a construction site. The problems generated by waste management on site were also determined, including the need to find the space necessary to segregate and process selected types of waste.

The next step was to suggest a solution that would help to reduce the stream of waste discharged from a construction site, i.e. a proposal to use the waste for the production of further construction products used on site. The research process ends with a summary leading to conclusions from the implementation of the proposed solution. The research process is shown in Figure 3.

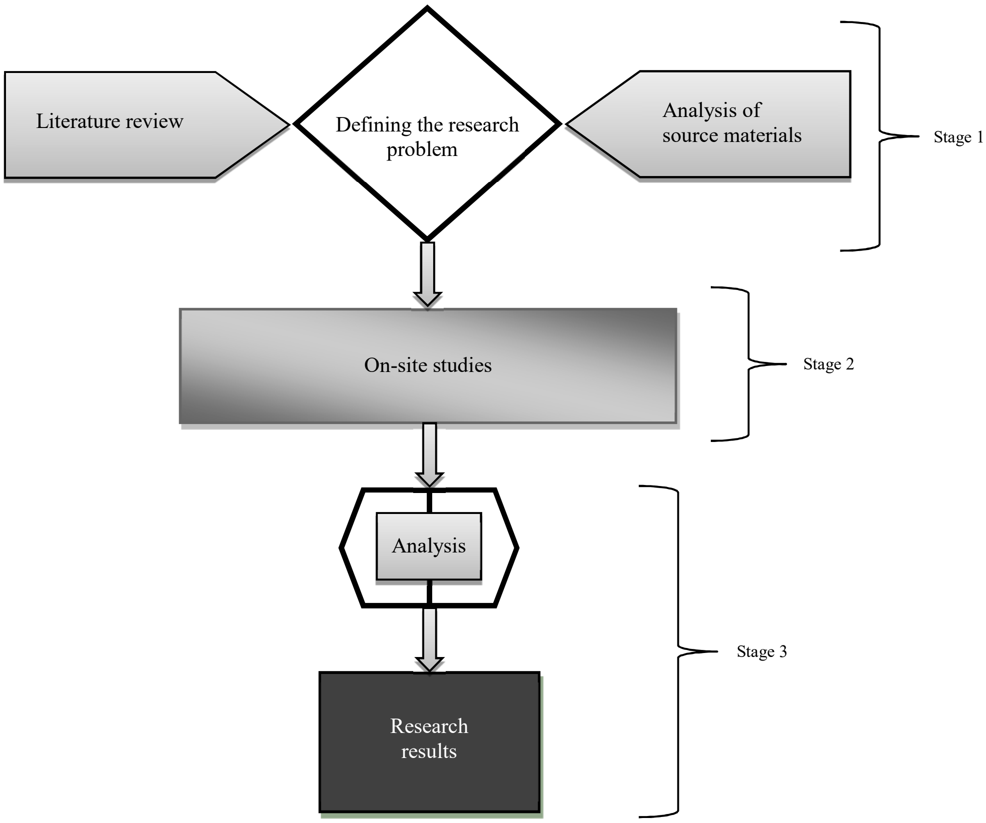

Fig. 3. The research process (*own research*)

2. Results

In line with the circular economy and its foundations, we speak of a closed circle of construction materials and products, but the whole circle closes when a building is demolished. It seems justified to add to the circle's smaller loops that will take into account the use of waste at the construction site where this waste is generated. This may also apply to the stage of preparing and producing construction materials and products, as well as later stages, such as construction itself or the useful life of a building (Fig. 4).

Because most of mixed construction waste is generated on a construction site, the objective of this research was how such waste could be utilized on site. This approach calls for certain organisational measures, including such planning of a construction site that provides enough space to store and process the waste (Fig. 5).

Following the hierarchy of steps in the procedure recommended by regulations on waste, the possibility of processing waste on a construction site deserves special attention. A variety of methods and technologies can be employed to process waste where it is generated. One option is to crush it. Crushing can be applied to construction debris, styrofoam from insulation and packaging, and glass. Crushed material can be then used as insulating backfill, an additive to concrete and mortar (partial aggregate substitute) or as a soil improver in landscaping after the completion of construction works. Another method is the fragmentation of materials that cannot be crushed, for example plastics, paper, textiles, but which can be added to concrete mixture or mortars after shredding. Some of such shredded waste can also be used as different types of loose levelling or insulating layers, and in the landscaping of the surroundings of buildings under construction. Styrofoam can also be dissolved using organic solvents. The resulting liquids can be used for hydro-insulation or as impregnates. In order to be able to carry out such waste processing on a building site, it is necessary to create a waste management area (scheme on Fig. 6). It should include a selective waste collection and storage point, a place for waste processing, a place for preparation for use on the construction site, points for the production of concrete mixtures with the addition of shredded waste, and a place for the production of construction products from such mixtures. Our research has led to the following solution, illustrated in Figure 6.

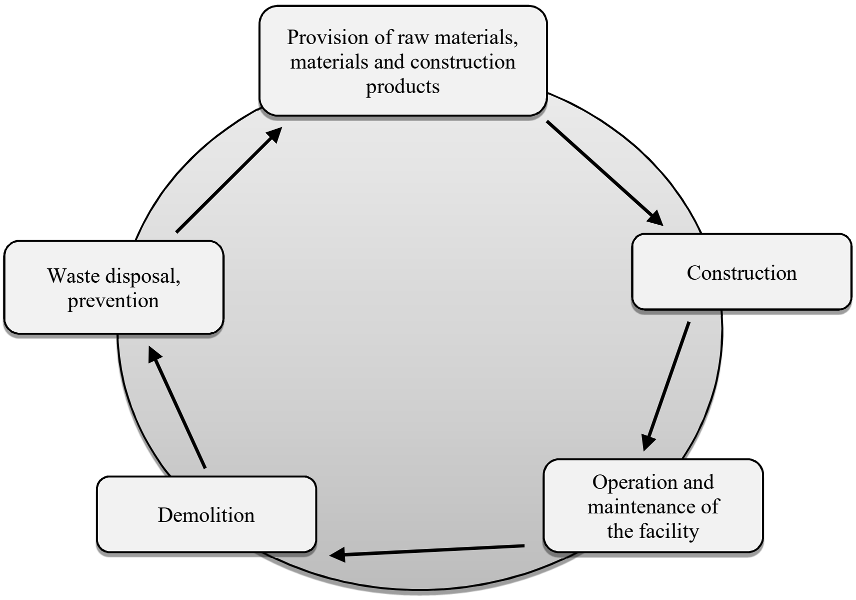

Fig. 4. Modernized circular economy scheme in construction (*own research*)

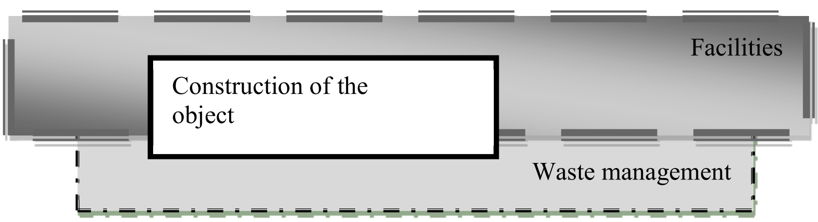

Fig. 5. Organization chart of the planned construction (*own research*)

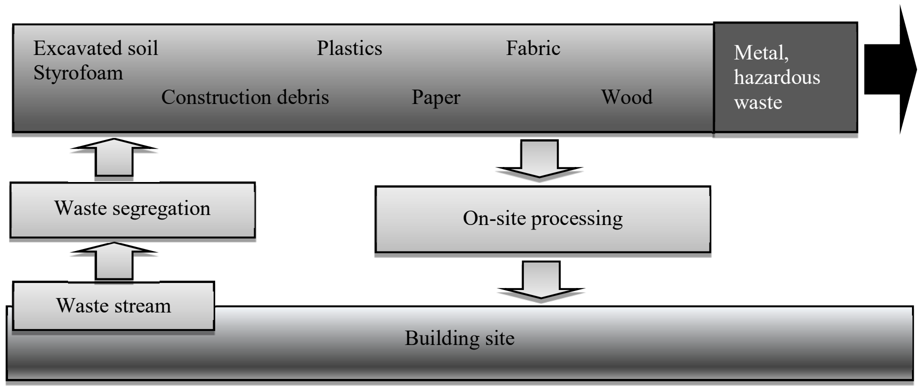

Fig. 6. Proposal for a solution for the new circular economy proposal in construction (*own research*)

It is also necessary to arrange a place for storing waste that cannot be processed or reused on the construction site. These include hazardous waste, paint and varnish residues, paint and varnish packaging, metal, roofing paper and mastic waste.

3. Discussion

There are many solutions for processing waste generated during construction. In the proposals dominating in the literature, we can find mainly activities related to the removal of waste to segregation points and their processing at points prepared for this purpose. This involves transport, often over long distances, which generates an additional burden on the environment. In the available literature on the subject, it is difficult to find proposals for the management of waste generated during construction (mainly from packaging) on site. Considering the fact that approximately 80 % of such waste can be recycled, the suggested approach seems noteworthy.

The proposed solution provides for the processing of some waste on site, which gives measurable benefits for contractors and investors, and above all, reduces the burden on the environment. One of the advantages of the proposed solution is the reduction of the mass of waste exported, the reduction of transport related to it, and the associated costs. Furthermore, the use of recycled materials leads to a lower demand for such building materials as aggregate or loose insulation materials. Besides, with good work organisation, it is possible to use shredded construction waste as an additive to concrete and to make small concrete products, for instance paving tiles, plant pots, walls, needed for the landscaping of a site. Such products can be made from mixtures containing shredded waste.

The proposed method also has disadvantages. One of them is the need to prepare a place on the construction site for waste segregation and collection. It also requires space to organize waste processing points for use on site and to organize a specialized work team that can take care of these activities.

Analyzing the advantages and disadvantages, it can be seen that the benefits of implementing this method may be more than the disadvantages. Bearing in mind the opportunities for the development of environmentally friendly technologies, resulting from the constantly changing requirements for an ecological approach to economic activity, it can be assumed that the solution, which is the subject of this research, will be used in practice.

The issues presented in the article are part of the author's research. Their subsequent stages provide for laboratory tests of materials and products obtained by adding shredded waste to their production.

4. Conclusion

To summarize the results of our study, the proposed solution seems to move in a good direction in the framework of construction waste management theories. The most important conclusion drawn from this study is that the waste generated during a construction project is best to be managed on the construction site, and consequently this will help to supplement the circular construction cycle scheme. Obviously, both the actual plans to create such waste processing facilities on a construction site, including waste processing technologies implemented, and the use of recycled materials can vary. Having refined the solutions adjusted to the technologies used on a given building site, it is possible to develop a unique solution that will be best suited for a given development project. Both waste recycling technologies and possibilities of manufacturing new building materials or products with the use of processed construction waste deserve further research, including laboratory tests. The proposed solution allows for some reduction of the waste that must be removed from a construction site, less transport and consumption of fuels, less pollution caused by motor vehicles, reduction of the traffic load on roads, and less noise on roads, which all contribute to the implementation of the green building policy.

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