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COST ANALYSIS OF CONCRETE RECYCLING IN ROAD WORKS: A CASE STUDY ON CIRCULAR ECONOMY IN THE CONSTRUCTION SECTOR

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Abstract

The integration of recycled materials into technical solutions for new constructions and the rehabilitation of existing infrastructure remains a significant challenge in the transition towards a circular economy.

This paper examines the feasibility of using recycled concrete in road infrastructure projects, considering the characteristics of Romania's aging building stock, which predominantly consists of reinforced concrete structures. A case study was conducted to assess, from an economic perspective, three scenarios for constructing a shape layer for a county road: without recycled material, with partial use (50%) of recycled concrete, and with full utilization of recycled concrete. The results indicate that the scenario involving the complete use of recycled concrete offers the most cost-effective solution per linear meter. While the conclusions of this case study are limited to the specific conditions analyzed, they provide valuable arguments for incorporating recycled concrete into road infrastructure projects. Furthermore, the study highlights the need for extended research through additional analyses on a larger sample of reinforced concrete structures to validate the reuse potential of such materials under optimal technical and economic performance conditions. The development of the market for recycled materials, including their application in transport infrastructure, can lead to significant cost savings in both construction and maintenance, thereby supporting the objectives outlined in the national circular economy strategy. Future research could focus on the simulation and assessment of sustainable materials, such as eco-concrete, in the context of their recycling and reuse in the construction sector.

Keywords: circular economy, recycled concrete, road infrastructure, cost analysis, life cycle costs

1. INTRODUCTION

The circular economy is more and more present in all areas of activity, with principles and concepts transposed including in the construction activities, having impact on both the chosen technical solutions and on the economic aspects, while taking into account quality assurance constraints. In the framework of transition to circular economy in the field of construction, the recovery and reuse of materials from existing buildings becomes a strategic direction of research and practice. This aspect is also highlighted in the Romanian National Strategy on the circular economy from 2022.

Data from the population and housing census (2021) indicate that in housing, the stock of houses from the built environment has aging trends, 62.51% of the built-up buildings have more than 50 years of life, and among them 34.57% are reinforced concrete or masonry buildings with reinforced concrete slabs and/or metal beams (see Figure 1). Thus, the approach to concrete recycling becomes an excellent example of practice in the circular economy, turning a material considered waste into a valuable one. This process supports sustainability in construction (Jayawardana et al., 2025, Grecu, 2023), providing an environmentally friendly alternative to traditional building materials and reducing dependence on finite resources.

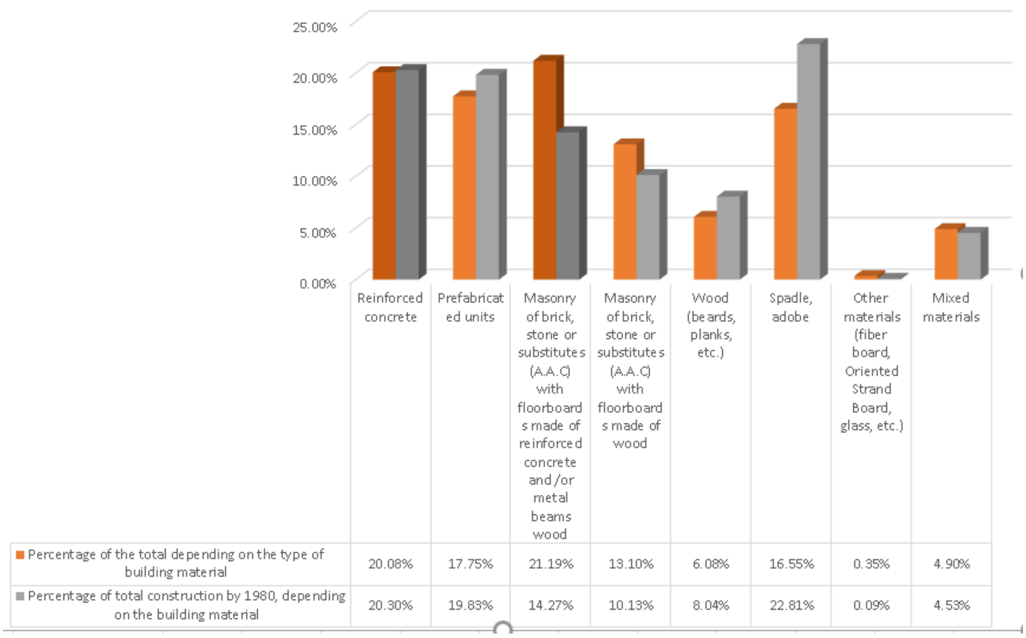

Figure 1. Share of conventional residential buildings in Romania by type of material built (*source*: calculations of authors based on data from Census of population and housing, 2021 – table 8.2. INSSE)

Concrete recycling involves the conversion of demolition and renovation concrete waste into new and useful materials. The process begins with the collection and transport of concrete waste to a processing location. Here, the materials are sorted, cleaned of impurities, and finally crushed into aggregates of varied sizes (Fan et al., 2016, Nikmehr et al., 2024). These aggregates can then be used in new concrete production, road infrastructure works, or other construction applications. The recent literature highlights that reuses are technically viable in proposed/chosen technical solutions (Valdés-Vidal et al., 2020, Mangoro et al., 2025) or executed ones (Çimen, 2021), technical constraints and opportunities (Oreto et al., 2024, Valdés-Vidal et al., 2020, Liu & Kringos, 2024). Chemical and physical analysis of the properties of materials used in road infrastructure (Abdalla et al., 2025, Valdés-Vidal et al., 2020, Çimen, 2021, Mascarenhas et al., 2023, Khan et al., 2024) could also be identified. Legal constraints in the reuse of materials (Liu & Kringos, 2024), as well as approaches related to life cycle management (Presti et al., 2023).

From a management perspective, approaches included analysis of ICT-based decision support tools applied to implement construction circular economy (Yu et al., 2022) of managing resources, focus on the impact of sustainability on the labor market and employability in the construction sector (Silvestru et al., 2024), management of material and stock flows (Miatto et al., 2015, Ataee & Stephan, 2025). The research focused mainly on case study analyses and in-depth analyses relevant to a particular country (Italy - Oreto et al., 2024, USA - Miatto et al., 2015) or several countries in Europe (e.g. Presti et al., 2023), Asia (e.g. China- Çimen 2021), Africa (e.g. Mangoro et al., 2025).

An important dimension is related to environmental protection, addressing issues related to the management of construction and demolition waste and their valorisation in the literature (Çimen, 2021), taking into account the life cycle assessment (Chen et al. 2025, Mangoro et al., 2025), as one of the dimensions that have shown high interest in the analyses in recent years (Çimen, 2021).

Concrete recycling offers significant cost savings, both in terms of waste disposal and the purchase of new materials, recycled aggregates can be cheaper than extracted ones (Liu & Kringos, 2024, Khan et al., 2024), without compromising quality or performance.

Life cycle assessment approaches could also be identified, with different connections, such as those related to the circular economy in the built environment (Lei et al., 2021) or life cycle costs (Miah, Koh & Stone, 2017).

Following the literature checks, although the analysis niches of material use and waste recovery are very often analysed (Çimen, 2021), from the perspective of circular economy and sustainability, we believe that the approach of such an analysis from the perspective of managing the costs of infrastructure use of recycled materials in investments in Romania can be conducted, and considering an analysis of the overall costs of a civil building on its life cycle, with the use of recyclable materials in road infrastructure.

Therefore, this research aims to analyse the recycling potential of reinforced concrete from old structures, with the aim of using it in road infrastructure, from a cost perspective, including considering the overall life cycle costs of the old building. For this, a case study is conducted on an existing building - the C7 student residence building of the Technical University of Civil Engineering Bucharest (TUCEB), a building built in 1982, with a structural system of precast reinforced concrete panels. The building has a height regime of Basement, Ground Floor, 10 Floors, Setback Floor, a developed area of about 10,560 square meters (m^2) and an estimated interior volume of 24,060 cubic meters (m^3). The analysis of this construction provides a concrete framework for assessing the quality of concrete and the feasibility of the recycling process in a real urban context.

2. METHODOLOGY

For the purposes of this case study, the following aspects have been considered (see Figure 2):

1) A demolition building was identified, for this the overall costs were estimated, also a calculation of the quantities of recyclable reinforced concrete was made and the related updated costs were estimated.

2) There were identified 3 options of a technical solution for achieving a road infrastructure – a county road 7 m wide with a layer of 40 cm thick, of which one of the options in which the road instruction is made of ballast, without recyclable material (reference version), a mixed option that includes recyclable concrete and ballast (50%-50%, respectively that is 20 cm of recyclable concrete and 20 cm ballast) and a option with a full layer of recycled concrete.

3) The costs per linear metre and for the road option considered for identifying the cost-recommended option were analysed, followed by the calculation of the overall cost / per life cycle for the investment of the building concerned for demolition.

4) A simulation of the costs associated with the use of recyclable reinforced concrete that can be recovered, given that the building would have been made of eco-concrete in the studied building was carried out.

5) The costs per linear metre and road option considered under the conditions of use of eco-concrete recyclable material were again analysed to identify the cost-recommendable option with the calculation of the overall cost / life cycle for the investment of the building under consideration.

6) The two analyses were compared, with cost management options being proposed considering the characteristics of recoverable crushed concrete (classical vs. eco-concrete).

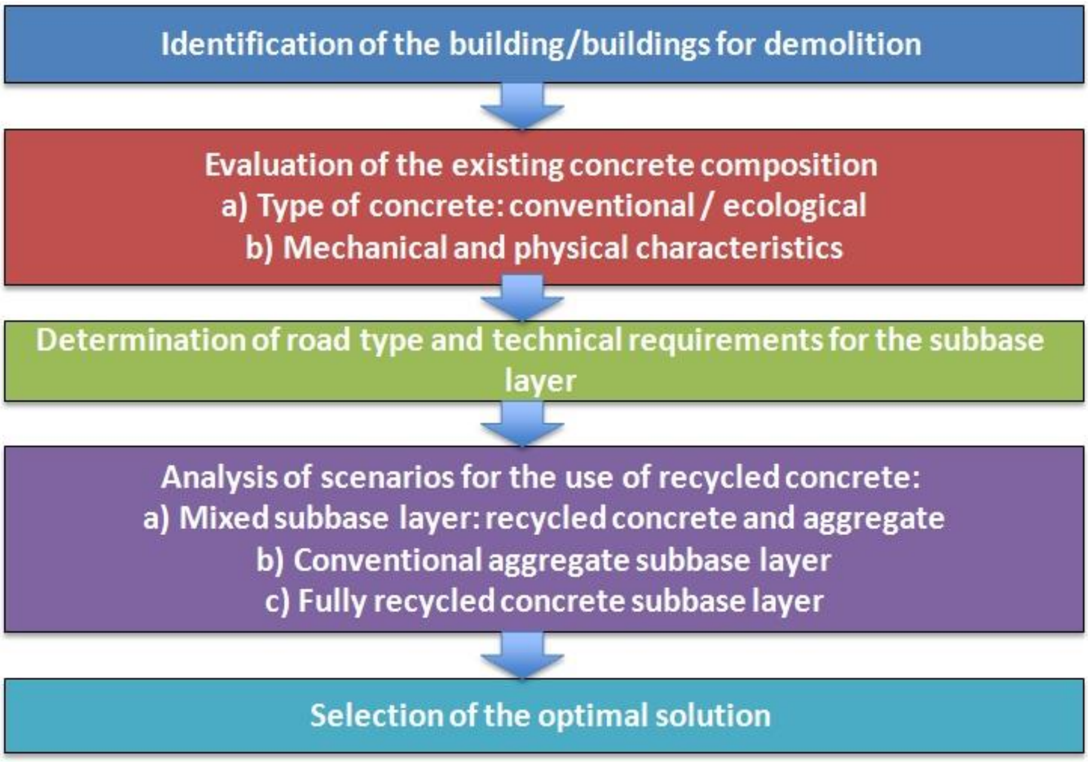

Figure 2. Research design (*source*: authors' representation)

To assess the potential for re-use of existing construction concrete, a representative building on the TUCEB campus has been selected from C7 – since 1982. The choice was based on the following criteria: structural system made entirely of precast reinforced concrete, significant volume of embedded material, documented technical condition and lack of major consolidation interventions. The building has a height regime of Basement, Ground Floor, 10 Floors, Setback Floor and a developed area of about 11,000 m², which makes it relevant for quantitative analysis of recoverable resources. The evaluation was carried out in accordance with the C254-2022 methodology (MLPAT, 2022), supplemented by field observations, visual investigations and historical data, to characterize the quality of concrete and the structural condition of the analyzed components.

Estimates of recoverable material were made based on preliminary measurements, resulting in an amount of about 4,572 cubic meters (m^3) of concrete and recyclable reinforcement.

For the analysis of the estimated costs related to recyclable concrete that can be recovered from the building concerned, the costs of using dedicated software (Windev) were updated, which considered the estimated average prices of materials on the construction market for the period considered. The cost update was made considering the regulations in force (MLPAT a, 1992, MLPAT b, 1992).

Limitations of research

Given that the cost analysis calculations are based on estimates, not on actual data obtained from the demolition of an existing building, the analysis data present a margin of error that we consider acceptable. Cost estimates for recyclable concrete are made on a building with certain technical characteristics of concrete, resulting from technical expertise after a certain service life (over 40 years).

Cost estimates are based on preliminary measurement; estimates based on current modern techniques, such as BIM, can provide other data in cost analysis with a different level of accuracy, which implicitly influences the results of the analysis. Such a model may be the subject of further research. In carrying out the cost analyses, transport costs were not considered as different distances from the crusher to the site of the yard can significantly influence the results of these calculations.

Cost update estimates are based on updated average costs, made by the software used (Windev), and may result in slightly modified cost values when using other software.

We can also consider that the technical properties of recoverable crushed concrete may be similar, provided that the same technical regulations are complied with in the construction of the civil construction, but expertise of the recovered recyclable material is required to ensure the similar technical performance of the recoverable material.

3. ANALYSIS OF RECOVERABLE CONCRETE COSTS THAT CAN BE USED IN ROAD INFRASTUCTURE

Identification of the demolition building

As mentioned in the section on research methodology, the analysis is conducted as a case study on an existing building: the C7 student residence building, built in 1982 in the TUCEB premises, which is the material source for the analysis of recoverable concrete.

The structure is made up of precast reinforced concrete panels with continuous floor and foundation of the same material, according to the regulations P100-81 (MDRAP, 2013). The interior volume of the building is about 24,060 cubic meters, of which a significant proportion is occupied by concrete structural elements. Recent evaluations (at 2025 level) indicate a good overall technical condition with no significant structural damage or major interventions. Degradations are localized and minor, consisting of fine cracks and degradations of finishes, without exposure of the reinforcement or loss of bearing capacity. These characteristics suggest a good preservation of the quality of the material, favorable for the process of recovery, recycling and further use in road construction.

Following the estimative calculations made, based on preliminary measurements, resulted in a recoverable amount of about 4,572 cubic meters of concrete and recyclable reinforcement.

Establishing the type of road and the requirements of the shape layer

To demonstrate the advantages regarding the cost of re-use of the material, a layer of form consisting entirely of ballast (40 cm) is proposed for comparison, as was also mentioned in the research methodology. Thus, it will represent the baseline scenario in the analysis (scenario 2), scenario 1 representing the cost analysis with the use of one ballast layer (20 cm) and recyclable reinforced concrete (20 cm). The shape layer in all conceptions of road complexes is the top layer of embankments that fulfils a number of roles during the execution of works (short-term rolls) and provides a uniform and constant load-bearing capacity at the base of the road structure over the entire lifetime of the construction (long-term roll) (Marc, 2011).

The shape layers are made of:

a) non-cohesive materials:

- noncohesive lands,
- 10 cm existing or gravelled land surfaces of minimum thickness.

b) cohesive materials:

- mechanically stabilized cohesive earths,
- cohesive earths treated with lime,
- cohesive earths stabilized with granulated slag and lime (Marc et al., 2018).

When making the shape layers, stone quarry waste as well as alluvial granular materials can be used (Alzara et al., 2024). The technical features taken into account for the recycled concrete were referenced to SR EN 13242 (2008) on aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction (ASRO, SR EN 13242:2008). The thickness of the shape layer is provided in the project or in the specifications, and the slopes in the transverse profile of the surface of the shape layers are the same as the surface of the clothing (Lucaci et al, 2000).

Analysis of the use scenarios of recycled concrete, recoverable from the existing building

The cost calculation of the 20 cm recycled concrete shape layer was made for a 7 m wide road. The amount of recycled concrete needed to secure the 20 cm layer for a linear meter (lm) was calculated, resulting in a value of 1.4 mc/lm. Based on this calculation, the length of the county road that can be made with recyclable material was later calculated. Thus, the 4,572 cubic meters (results from the forerunners, aspect specified in the section Methodology), can be used for the construction of a road in length:

$$L = \frac{Q_r}{q}, \tag{1}$$

where $L =$ the total length of the road that can be built, $Q_r =$ the total amount of recycled concrete (m³) and $q =$ the amount of material required to construct a linear meter of road (m³/m), without taking into account the coefficient of correction for compaction, loss or error. Applying the formula (1) for the quantity of concrete available, we get the following length of a county road:

L = 4,572 m³ : 1,4 m³/lm = **3265.7 lm**.

These values are taken by reference for the calculations made for the 3 analysis scenarios.

For the analysis, the formula for the total cost of crushing recycled concrete will be used:

$$C_{tcc} = \left(\frac{Q_r}{P_d} \right) \times C_{cd}, \tag{2}$$

where Q_r = the amount of recycled concrete (mc), P_d = crusher productivity per day (m³/day), C_{cd} = crusher cost per day (euro/day).

To note that $\frac{Q_r}{P_d}$ = represents the number of days for crushing. In this case, for the building under review, applying formula (2), based on current average costs used by practitioners at the level of 2025, where Q_r = 4,572 m³, at a cost P_d = 140 euro/m³ and a cost C_{cd} = 1100 euro, will result:

$$C_{tcc} = \left(\frac{4572}{140} \right) \times 1100 = 35{,}922.35 \text{ euro}.$$

Starting from the formula (2), one can also determine a unit cost per cubic meter of recycled concrete, given by the formula (3):

$$C_u = \frac{\left(\frac{Q_r}{P_d} \times C_{cd} \right)}{Q_r} = \frac{C_{cd}}{P_d}. \tag{3}$$

Following the application of formula (3) for the analysed building, for C_{tcc} = 35.922,35 euro and Q_r = 4,572 m³, it results:

$$C_u = \frac{\left(\frac{4572}{140} \times 1100 \right)}{4572} = 7.86 \text{ euro/m}^3.$$

Following the cost analysis, for scenario 1, on the costs of making the 20 cm recycled concrete layer of form, put into operation, the following results (see table 1):

Table 1. Calculation of the costs of making the 20 cm recycled concrete layer, put into operation, related to scenario 1 (*source*: the calculation made by the authors, 2025)

Type of cost	**Calculations related to costs**
Cost of crusher	1100 euro/day
Productivity	140 m³/day
Unit cost crushing	7,85 euro/m³
Cost of workmanship/in recycled concrete	10 euro/m³

Type of cost	**Calculations related to costs**
Unit cost recycled concrete put into	7.85 euro/m³ + 10 euro/m³ = 17.85 euro/m³
Total cost of crushed concrete	4,572 m³ x 17.85 euro/m³ = 81,610.2 euro
Cost of recycled concrete form per lm	1.4 m³/lm x 17.85 euro/m³ x 1 lm = 24.99 euro/lm
Total Cost recycled concrete shape layer	3265.7 m x 24.99 euro/m = 81.609,84 euro

Following the calculation for the ballast part of the shape layer, for 20 cm ballast, put into operation, in the first scenario, the following results (see table 2):

Table 2. Calculation of the cost of making the ballast layer, of 20 cm, put into operation, related to scenario 1 (*source*: calculations made by the authors, 2025)

Type of cost	**Calculations related to costs**
Ballast acquisition cost	34.5 euro/m³
Ballast cost in	34.5 euro/m³ + 10 euro/m³ = 44.5 euro/ m³
Cost ballast shape layer	3265.7 m x 7m x 0.2 m x 44.5 euro/m³ = 203,453.11 euro

For scenarios 2 and 3, the related costs for making the ballast shape layers were doubled, without recycled material (second scenario) and the recycled concrete shape layers (third scenario) being the comparison between the 3 scenarios, as shown in Table 3.

Table 3. Comparison of scenarios of making the recycled concrete shape layer, for a county road of 7 m wide and 3265.7 m long, with highlighting the cost savings (*source*: calculations made by the authors, 2025)

Scenario analysed, mentioning the technical solution of the road analysed	Calculation scenario analyzed	Total cost/ analysed scenario	Calculation Cost savings	Cost savings achieved for the analysed scenario	Cost savings achieved per linear metre for the analysed scenario
S 1- recycled concrete shape layer + Ballast	81,609.84 euro + 203,453.11 euro	285,062.95 euro	406,906.22 euro - 285,062.95 euro	121,843.31 euro	121,843.31 euro: 3265.7 m = **37.31 euro/lm**
S 2- ballast shape layer (without recycled material)- reference point	203,453.11 euro x 2	406,906.22 euro			
S 3- recycled concrete shape layer	81,609.84 euro x 2	163,219.68 euro	406,906.22 - **163,219.68** euro	243,686.54 euro	243,686.54 euro :3265.7 m = **74.62 euro/lm**

As can be seen from Table 3, the most economically advantageous option is to make the recycled concrete shape layer (S3).

Presentation of the calculations on the overall cost / cost per life cycle of the existing building, considering the scenarios analyzed

For the calculation of costs, from a life cycle perspective (Mehedințu & Postăvaru, 2016, Challender, 2024, Munteanu & Mehedințu, 2016), this analysis focused mainly on initial costs (design and execution, without land acquisition) costs of periodic/regular maintenance and reuse (rehabilitation/restoration, renovation), as well as recovery costs (demolition, decommissioning) and postusage costs related to recycling. Operating costs have not been considered. The analysis of the operating costs may be the subject of a separate study, carried out from the perspective of facility management, which considers the operation of own operations and/or outsourced operating services, with possible cost optimizations depending on the chosen mix of building management (Gunduz et al., 2023). This analysis is not the subject of interest in this article. Thus, we will use the following calculation formula:

$$\begin{aligned} C_{life\,cycle} &= C_{\text{initial}} + C_{\text{maintenance and rehabilitation}} + C_{\text{demolition}} - C_{\text{recycle}} \\ &= \left(C_d + C_e\right) + C_{mr} + C_{dem} - C_{recycle} \end{aligned}, \quad (4)$$

where C_d and C_e these are the initial costs of design and execution, C_{mr} represents costs of for regular maintenance and rehabilitation, which are for the 5 major interventions done regularly every 10 years, C_{dem} it is the estimated cost of demolition and decommissioning at the end of the construction life cycle, and $C_{recycle}$ represents the costs for recycling the recovered reinforced concrete from the building. For the estimation of initial investment execution costs, the global method of estimating the value of a construction object is related to the estimated cost of the structure (see Table 4).

The calculation of the estimated cost of the material in the structure of resistance, namely concrete and reinforcement is about 3,716,765 RON without VAT, which is 743,353 euro, at an average euro rate of 5 RON, according to the analytical estimate. The inventory value of the building was not used, updated with depreciation, but its value was estimated based on a cost simulation related to the quantities in the forerunners and current prices in the market.

In order to calculate the total cost of the resistance structure, it will be considered the hypothesis in which the price of the material represents 40%, so that the total cost of the structure is 9,291,912 RON (1,858,382.5 euro), according to the following percentage distribution very often used by practitioners in Romania: materials – 40%, labour 20%, equipment 20% and transport 20%.

For the calculation of the cost of production of the building, the global method of estimating the value of a construction object allows the following approximation, shown in Table 4, as a percentage of the cost of the structure of resistance:

Table 4. Calculation of the price per physical stage and the total cost of execution/production of the building, calculated as a percentage of the cost of the resistance structure (*source*: calculations of the authors, based on some percentages resulting from the practice in Romania)

Physical stage	**% cost of the resistance structure**	**Physical stage price (RON)**	**Physical stage price (euro)** ***1 euro = approx. 5 RON***
Structure		9,291,912	1,858,382.4
Architecture	200%	18,583,824	3,716,764.8
Embankments & infrastructure	50%	4,645,956	929,191.2
Total cost of execution		**32,521,692**	***6,504,338.4***

Thus, the cost per square meter is about 616 euro (6,504,338.4 euro/10,560 m² = 615.94 euro/m²).The estimation of design costs is done in relation to the total cost of execution, with reference percentages based on average values used in practice in the construction market in Romania. Thus, the following initial costs were estimated (table 5):

Table 5. Calculation of initial estimated costs related to design, based on average values used in the construction market in Romania (*source*: calculations of the authors)

Type of cost	**% of the total cost of execution**	**Cost (RON)**	**Cost (euro)**
Cost studies	1%	325,216.92	65,043.38
Cost design	6.60%	2,146,431.67	429,286.33
Cost reception	0.20%	65,043.38	13,008.68
Cost management	1.35%	439,042.84	87,808.57
Total		**2,975,734.81**	***595,146.96***

For the costs of periodic/regular maintenance and rehabilitation /restoration, the option of maintenance mainly with own personnel was considered. It was taken into account that the building undergoes interventions every 10 years, for larger works on the building, given that the life of a civil construction was considered to be 50 years (Challender, 2024), at an average cost of approximately 150 euro/m² (average cost obtained from authors' studies of prospecting the market in 2025).

Thus, the costs of periodic maintenance and rehabilitation/restoration for the 5 interventions done on the building every 10 years represent a total cost of ***7,920,000 euro*** (10,560 m² x 150 euro/m² x 5 interventions).

The demolition costs were estimated on market data from 2025, with an average of 495 RON/m², which represents 99 euro/m². Thus, total demolition costs for the building analysed are of ***2,263,140 euro*** (4,572 m² x 495 RON/m²).

Given that recovering and reuse of materials contributes to reducing life cycle costs for the analysed building, when taking into account the proposed scenario (scenario no. 3, with total of savings of ***163,219.68 euro***), when using the previously mentioned formula (4), the life cycle costs for the existing building are:

$$C_{life\,cycle} = \left(595{,}146.96 + 6{,}504{,}338.4\right) + 7{,}920{,}000 + 2{,}263{,}140 - 163{,}219.68$$
$$= 17{,}119{,}405.68 \text{ euro}$$

A simulation of the costs associated with the use of recyclable reinforced concrete in the studied building, which can be recovered, given that the building would have been made of eco-concrete

From the perspective of life cycle costs, taking into account the same methodology based on preliminary measurements, similar demolition costs would result, given that similar quantity of recovered material will be obtained and its recycling will have similar costs. Thus, the proposed scenario for the road layer will be the same as for the existing building.

Differences however may occur when taking into account life cycle costs for the building which could be made with eco-concrete, that can be later on recycled and reused. Therefore, a similar analysis from the perspective of life cycle costs is conducted further, using the same formula (4).

In this simulation, costs for eco-concrete identified showed an average of 391 RON/m². Thus, when calculating the costs for the structure for a similar building as in the previous case, we estimated them using the same methodology, the same data from preliminary measurements. The resulting estimated costs for the structure would be of 391 RON/m³ x 4,572 m³ = 1,787,652 RON, or 357,530.40 euro.

Similar calculations for the total structure costs were made, based on the same hypothesis as before, in which the material price represents 40%, resulting in a total of 4,469,130 RON, equivalent of 893,826 euro.

For the calculation of the cost of production of the building, the global method of estimating the value of a construction object allows the following approximation, shown in Table 6, as a percentage of the cost of the structure of resistance:

Table 6. Calculation of the price per physical stage and the total cost of execution/production of the building using eco-concrete, calculated as a percentage of the cost of the resistance structure (*source*: calculations of the authors, based on some percentages resulting from the practice in Romania)

Physical stage	**% cost of the resistance structure**	**Physical stage price (RON)**	**Physical stage price (euro)** ***1 euro = approx. 5 RON***
Structure		4,469,130	893,826
Architecture	200%	8,938,260	1,787,652
Embankments & infrastructure	50%	2,234,565	446,913
Total cost of execution		**15,641,955**	***3,128,391***

Thus, the cost per square meter is about 296.25 euro (***3,128,391*** euro /10,560 m² = 296.25 euro/m²).

As in the previous section of the analysis, the estimation of design costs is done in relation to the total cost of execution, with reference percentages based on average values used in practice in the construction market in Romania. Thus, the following initial costs were estimated (table 7):

Table 7. Calculation of initial estimated costs related to design for a building in which eco-concrete is used, based on average values used in the construction market in Romania (*source*: calculations of the authors)

Type of cost	% of the total cost of execution	Cost (RON)	Cost (euro)
Cost studies	1%	156,419.55	31,283.91
Cost design	6.60%	1,032,369.03	206,473.81
Cost reception	0.20%	31,283.91	6,256.78
Cost management	1.35%	211,166.39	42,233.28
Total		1,431,238.88	***286,247.78***

Taking into account same criteria for estimating costs for periodic / regular maintenance and rehabilitation / restoration, the option of maintenance mainly with own personnel was considered, with 5 interventions every 10 years, for larger works on the building, at an average cost of approximately 100 euro / square meter (average cost obtained from authors' studies of prospecting the market in 2025). Thus, the costs of periodic maintenance and rehabilitation / restoration represent a total cost of ***5,280,000 euro*** (10,560 m² x 100 euro/m² x 5 interventions).

The demolition costs were estimated based on market data from 2025, with an average of 495 RON/m², which represents 99 euro/m². Thus, total demolition costs for the building analysed are of ***2,263,140 euro*** (4,572 m² x 495 RON/m²).

Given that the recovering and reuse of materials contributes to reducing life cycle costs for the analysed building, when taking into account the proposed scenario (scenario no. 3, with total of savings of ***163,219.68 euro***), when using the previously mentioned formula (4), the life cycle costs for the existing building are:

$$C_{life\,cycle} = \left(286,247.78 + 3,128,391\right) + 5,280,000 + 2,263,140 - 163,219.68$$
$$= 10,794,559.10 \text{ euro}$$

Comparison between the two analyses, with cost management options proposed considering the characteristics of recoverable crushed concrete (*classical vs. eco-concrete*).

As results of the present analysis, several conclusions can be drawn, based on the comparison between life cycle costs in buildings from which crushed concrete is recovered and reused in road layer (Figure 3).

In both cases, the costs related to demolition and reuse of materials (crushed concrete vs. crushed eco-concrete) in road layer, are similar, given that similar technological processes are involved and similar quantities of materials are recovered from the building. Thus, in this case, other criteria should be considered in the decision related to usage of crushed concrete vs. crushed eco-concrete, , such as technical specifications, with further analyses possible to be conducted or with taking into account additional regulations that may be approved in the future in relation to the usage of recovered materials. In terms of quantity of material used in road shape layer, the decision to use a specific option was analysed from economic point of view, showing that in the case of a county road, with shape layer of 40 cm, the most economically advantageous option is to make the entire shape layer out of recycled concrete, instead of recycled concrete shape layer + ballast or ballast shape layer (without recycled material).

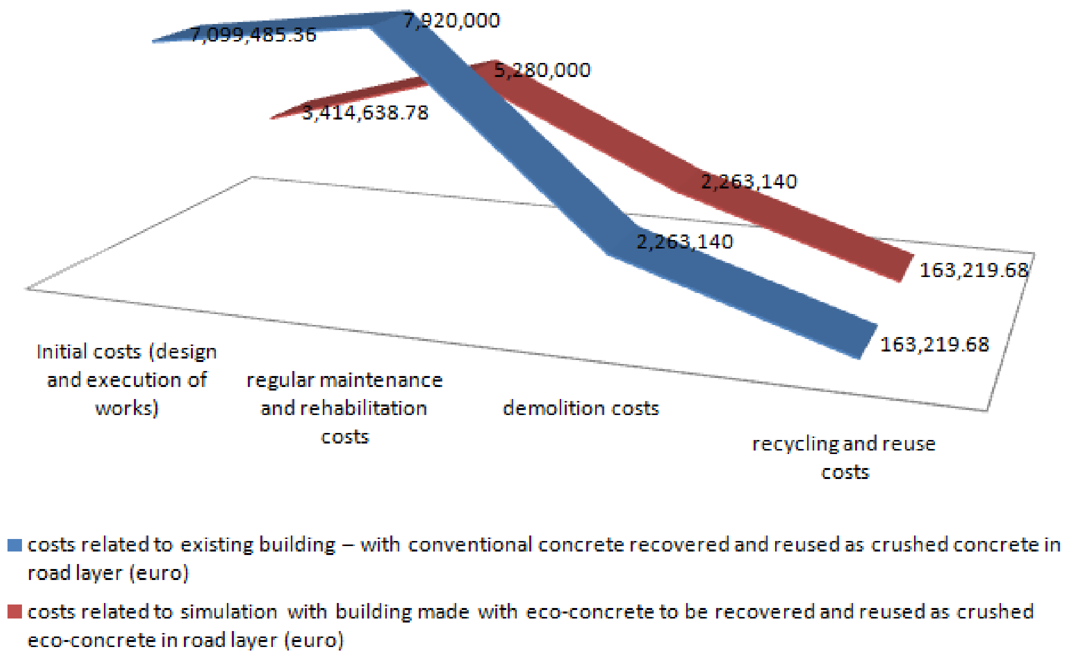

Figure 3. Comparison of life cycle costs for existing building made with conventional concrete with those of building (simulation) made with eco-concrete (*source*: authors' representation)

Should an investor plan to invest in a building made with concrete, decision on the type of concrete to be used can be made, deciding whether to use conventional concrete or eco-concrete. The analyses showed that the costs are similar from the perspective of recovering and reusing material (crushed concrete vs. crushed eco-concrete). Differences result more in terms of initial costs (design and execution costs) and costs related to maintenance and rehabilitation every 10 years, favouring the option of usage of eco-concrete.

4. CONCLUSIONS

The circular economy will continue to raise a number of challenges in including recovered, recycled materials in technical solutions for new construction or for the rehabilitation of existing infrastructure, including transport.

Given that in Romania the stock of housing from the built environment is aging and that the share of concrete use in conventional housing buildings is high, as was also highlighted in Figure 1, the analysis of the use of recycled concrete is timely.

From an economic point of view, in this article we have analysed, in a case study, the potential for recycling of reinforced concrete from old structures, with the purpose of using it in road infrastructure, focusing on the costs involved in various analysis scenarios highlighting possible cost savings. Thus, for the construction of a county road of 7 m wide with a shape layer of 40 cm thickness, 3 scenarios of achieving the technical solution were identified, one without the use of recyclable material, another with partial use (50%-50%) of recyclable material and the last with the realization of a fully recycled concrete layer.

The cost analysis per linear metre for the scenario that is advisable to consider indicates that the most economically advantageous option is the one for making the shape layer using only recycled concrete.

From the perspective of life-cycle cost analysis, demolition and reuse costs are similar, significant differences in investor perspective are related to initial costs, execution, as well as in the building operation period, which may influence decisions on the use of classic concrete or an option of eco-concrete, which is more environmentally friendly. In this regard, more detailed cost analyses on the building life cycle may be subject to further research.

This conclusion of this case study helps to strengthen the argumentation of including technical solutions that use recycled concrete in the construction of road infrastructure. The generalization of the conclusion of this case study presents its limitations, but we consider that the same building regulations for buildings are used during the construction period using reinforced concrete as in the case of this case study and possibly considered for more in-depth analysis on a significant number of buildings.

In other analyses, different directions may be more thoroughly approached with taking into account the potential for the recovery and reuse of building materials, allowing for example in-depth analysis of some aspects related to ensuring an adequate level of performance of various recyclable and reusable materials, under competitive market conditions, issues that are already addressed in the construction market, as evidenced by the national strategy on circular economy. Thus, the development of market demand and supply for recycled materials, including for use in transport infrastructure can contribute to cost savings in the realization / maintenance of transport infrastructure.

Other analyses may address simulations of the use of sustainable materials, such as eco-concrete, currently used in construction for its reuse following recycling.

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