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Life cycle analysis of reinforced concrete floor slab through three different waste management scenarios

Authors:

Ivana Carević, PhD. CE
University of Zagreb
Faculty of Civil Engineering
ivana.carevic@grad.unizg.hr

Helena Naletilić, MCE
Palace d.o.o
helenabradvica12@gmail.com

Prof.dr.sc. **Nina Štirmer**, PhD. CE
University of Zagreb
Faculty of Civil Engineering
nina.stirmer@grad.unizg.hr
Corresponding author

Preliminary note

Ivana Carević, Helena Naletilić, Nina Štirmer

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This paper presents a life cycle analysis (LCA) of a reinforced concrete floor slab with special emphasis on the end of life (EoL). Three EoL waste management scenarios were presented: Scenario I (current situation of construction and demolition waste management in the Republic of Croatia), Scenario II (100% landfilling of construction and demolition waste), and Scenario III (complete recycling of construction and demolition waste). The aim of this study is to demonstrate the environmental benefits of recycling in terms of sustainable construction and to determine the phases in the life of reinforced concrete floor slabs that have the greatest negative impact on the environment. From the analysis, the largest negative contribution to the environmental impacts is in the production phase, which includes the supply of raw materials, their processing, and the transportation of products to the concrete and reinforcement plants. EoL analysis showed that the manner in which construction and demolition waste is managed has a significant impact on the values of the impact categories of human toxicity (HTP), freshwater and marine aquatic ecotoxicity (FAETP and MAETP), terrestrial ecotoxicity (TETP), and eutrophication (EP). Conducting an LCA focusing on the EoL is critical, as it can provide valuable insights into the environmental impacts of the disposal phase and help develop strategies for sustainable waste management.

Key words:

life cycle assessment, reinforced concrete floor slab, waste management, sustainability

Prethodno priopćenje

Ivana Carević, Helena Naletilić, Nina Štirmer

Analiza životnog ciklusa armiranobetonske ploče kroz tri scenarija gospodarenja otpadom

U radu je prikazana analiza životnog ciklusa armiranobetonske podne ploče s posebnim naglaskom na kraj životnog vijeka. Prikazana su tri scenarija kraja životnog vijeka odnosno gospodarenja otpadom: scenarij I (trenutna situacija gospodarenja građevnim otpadom u Republici Hrvatskoj), scenarij II (100 % odlaganje na odlagalište) i scenarij III (potpuna oporaba građevnog otpada). Cilj je prikazati ekološke prednosti recikliranja u smjeru održive gradnje, ali i odrediti faze u životnom vijeku armiranobetonske podne ploče koje imaju najnegativniji utjecaj na okoliš. Na osnovi provedene analize, najveći negativni doprinos utjecaju na okoliš ima faza proizvodnje koja obuhvaća nabavu sirovina, njihovu obradu i prijevoz do mjesta proizvodnje samog građevnog proizvoda. Analiza kraja životnog ciklusa proizvoda pokazala je da način gospodarenja građevnim otpadom ima značajan utjecaj na vrijednosti kategorije utjecaja toksičnosti na ljude (HTP), pitku vodu (FAETP i MAETP), tlo (TETP) i eutrofikaciju (EP). Ocjenjivanje životnog ciklusa (LCA) s fokusom na kraj životnog vijeka je ključno jer može pružiti vrijedan uvid o utjecaju faze odlaganja na okoliš te pomoći u razvoju strategija za održivo gospodarenje otpadom.

Ključne riječi:

ocjenjivanje životnog ciklusa, armiranobetonska podna ploča, gospodarenje otpadom, održivost

1. Introduction

At the European level, the application of life cycle analysis (LCA) and the concept of life cycle thinking (LCT) are strongly promoted as auxiliary tools during the decision-making process and the responsible management of products and processes. LCA is a method used to determine how and in what ways various processes and products affect the environment during their lifetimes. It is a tool used to show the interaction between humans and nature. Further, during the production and manufacture of a product, there is a burden on the environment, which is determined by the LCA [1]. LCA can be used during the initial steps of the planning, design and construction processes, as a basis for selecting the approaches that have fewer negative impacts on the environment regarding materials, transportation, energy consumption, maintenance, waste management and processes of other phases of construction. The key element in the application of the LCT concept is that all relevant actors, producers and consumers become aware of environmental and social problems of the product/process and take action according to the results to solve the identified problems [2]. According to the *United Nations Environment Programme* [3], LCT takes into account all the impacts of every action at every stage of the life cycle, from 'cradle to grave'. Key actors cannot strictly limit their responsibilities to the phases of the life cycle of a product, process, or activity in which they are directly involved. On the contrary, LCT expands the scope of their responsibilities to include environmental impacts throughout the entire life cycle of a product, process, or activity. Different stakeholders can identify and prioritise the greatest burdens and risks and act comprehensively with solutions developed to reduce them. The life cycle of a product can be divided into several stages (modules):

- design and planning
- raw material extraction and processing
- production of products
- packaging and distribution
- use and maintenance
- end-of-life (EoL) management: reuse, recycling and/or disposal.

To promote the transition to a circular economy and the full implementation of the Waste Framework Directive (2008/98/EU) [4], consistent implementation of waste legislation in all EU member states is required, including the EoL of construction and demolition waste. Increasing recycling and reducing waste disposal are among the EU's priority waste management goals. Construction and demolition waste constitute the largest waste stream in Europe [5]. According to [6], one of the barriers to higher recovery rates is illegal dumping (Figure 1). The application of LCT and LCA contributes to integrated and systematic waste management that takes into account environmental, economic and social aspects [2, 3] and furthermore to the use and application of lessons learned in policies and national regulations.

In this study, a reinforced concrete floor slab made on-site was analysed using LCA to obtain quantitative information on its environmental impact during its life cycle. In addition, this study focused on comparing selected waste disposal alternatives from a life cycle perspective, considering both l andfill systems that do not involve recycling (Scenario II) and systems that can minimise the amount of waste to be disposed of while maximising material recovery (scenarios I and III). The aim is to consider the entire life cycle of the product as early as in the design phase and raise awareness of the negative environmental aspects of disposal, especially illegal disposal (Figure 1).

2. Methodology

The LCA was conducted in accordance with the HRN EN ISO 14040:2008 [7] and HRN EN ISO 14044:2008/A2:2020 st andards [8], which provide its basic principles and framework. The LCA was conducted in four phases:

- definition of the goal and scope of the research
- life cycle inventory analysis (LCI)
- life cycle impact assessment (LCIA)
- life cycle interpretation.

Figure 1. Illegal disposal of construction and demolition waste in populated areas (photo: private collection)

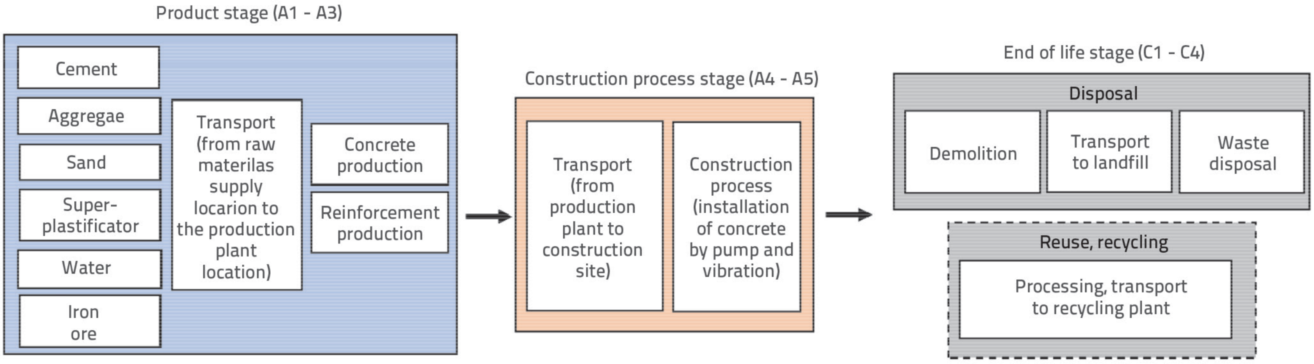

Figure 2. System boundary

2.1. Goal and scope, system boundary and functional unit

The goals of this study are as follows: (1) to quantify and evaluate the environmental performance of a construction product (reinforced concrete floor slab) and the contribution of each phase of the product life cycle to the environment and (2) to assess the life cycle of different waste management scenarios at the end of the product life in relation to the entire lifetime. The objective is to promote the recovery of materials and parts generated by demolition activities. In the construction industry, the strategy of material recovery and recycling helps reduce waste, save energy, reduce greenhouse gas emissions and reduce the consumption of natural resources [9]. The LCA was carried out on the construction of a reinforced concrete floor slab with expansions obtained by subsequent sawing, with a total area of 1000 m^2. The system boundaries of the "*cradle to grave*" LCA model for reinforced concrete floor slabs are shown in Figure 2 and include the following modules/phases (according to *HRN EN 15804:2019* [10]): 1) the product phase, which includes the supply of raw materials for the production of concrete and reinforcement, the transport of raw materials from the supplier to the production plant and the production of concrete and reinforcement from the raw materials at the production plant; 2) the construction phase, which includes the transportation of the concrete and reinforcement from the production plant to the construction site and the placement of the concrete and reinforcement (use of pumps and pervibrators); 3) the EoL phase, which includes the demolition of the reinforced concrete floor slab, transportation of the construction and demolition waste to the l andfill and/or recycling facility and waste disposal and/or recycling.

The functional unit may vary depending on the type of construction product. The authors [11] used two functional units: *the basic carrying capacity* and the *maintenance of a consistent floor depth*. Some studies used the mass of floor slab as functional unit [12-14], whereas in some studies the m^2 of floor slab was used as functional unit [15, 16], which was also applied in this case. In this work, 1000 m^2 was set as the functional unit based on the amount of material needed to make a reinforced concrete floor slab (Table 1).

Table 1. Estimated material quantities for the construction of a 1000 m^2 reinforced floor slab

Item	Unit	Quantity needed
Concrete	m^3	186
Reinforcement	t	14,9

2.2. Life cycle inventory analysis

LCI analysis involves data collection and calculation procedures to quantify the relevant inputs and outputs of a product system, in this case, the construction of a reinforced concrete slab including EoL. The products used for constructing a reinforced concrete floor slab are concrete and reinforcement. The concrete mixture was obtained from [11] and the input quantities of the raw materials for the production of 1 m^3 of concrete are listed in Table 2. The LCA modelling considered the extraction of raw materials (materials and energy for obtaining cement, aggregate, s and and superplasticiser), transportation of raw materials to the production facility/factory and production of reinforcement and concrete.

Table 2. Quantities of materials for the production of 1 m^3 of concrete [11]

Material	Unit	Amount	Data
Cement (CEM I 42.5R)	kg	365.00	Data of cement, aggregates, sand, water and superplasticisers were obtained from the EcoInvent database
Aggregate (4–16 mm)	kg	1015.00	
Sand	kg	965.00	
Water	L	221.00	
Superplastifikator	L	0.75	

Table 3. Different end-of-life (EoL) scenarios for the reinforced concrete floor slab

Scenario	European Waste Code (EWC) 17 04 05	European Waste Code (EWC) 17 01 01	Residue	Reference
SCENARIO I	100%	60%	40% disposal for EWC 17 01 01 at an authorised waste management company	Obtained from [19]
SCENARIO II	100%	0%	100% disposal for EWC 17 01 01 at an authorised waste management company	Assumption
SCENARIO III	100%	100%	-	Assumption

Table 4. Inventory data for the performance of a 1000 m² reinforced concrete floor slab

Phase	Inventory				Amount	Assumption
Product stage	Supply of raw materials	Concrete	Amount	m^3	186	Concrete modelled according to Table 2
		Reinforcement	Amount	t	14.9	/
	Transportation of raw materials to the production facility	Concrete	Cement – transport by truck	km	233	Cement is transported from the cement plant to the concrete plant in Zagreb (average distance)
			Coarse aggregate and sand - transport by truck	km	40	Coarse aggregate and sand are transported from the quarry to the concrete plant in Zagreb (average distance)
			Superplasticiser - transport by truck	km	5	Average distance between the distribution centre and concrete plant
		Reinforcement	Iron ore - transport by train	km	2258	Transport of iron ore from Asia to the rebar production site in Italy
	Manufacturing at the production facility	Concrete	Concrete mixing	MJ	EcoInvent database	
		Reinforcement	Production of reinforcement from iron ore	MJ		
Construction process stage	Transport from the production facility to the construction site	Concrete	Transport by truck	km	30	Concrete is transported from the concrete plant in Zagreb to the construction site (average distance)
		Reinforcement	Transport by train	km	451	The reinforcement is transported from Italy directly to the construction site
	Installation	Concrete	Pump	MJ	4199	Obtained from [17]
			Vibrating	kWh	127	Obtained from [17]
End of Life stage	Demolition	Reinforced concrete	Energy required for demolition	MJ	EcoInvent database	
	Transport to the disposal and/or recycling plant	Construction and demolition waste	Transport by truck	km	50	Construction waste is transported from the construction site to the place where the waste is disposed of and/or recycled

For this study, the locations of the raw materials and their use in production were assumed. It was assumed that cement is produced in Croatia and transported by road (truck) from a cement plant to a concrete plant in Zagreb. It was also assumed that the aggregates and s and were produced in Croatia and delivered from the quarry to the concrete plant in Zagreb (road transport truck). Data of cement, aggregates, s and, water and superplasticiser were obtained from the EcoInvent database. It was assumed that the superplasticiser was transported from the distributor to the concrete plant, with an average distance of 5 km (road transport truck). Potable water was used in concrete plants. One of the assumptions in this study was the production and transportation distances of the reinforcement. Iron ore is transported from Asia to a factory in Italy to produce reinforcement. The iron ore is transported by train. All distances between the place where the raw materials were obtained and the production facility were specified in kilometres, as listed in Table 4. Processing begins when all raw materials are delivered to the production facility. The production of construction products in a facility involves the mixing of concrete and reinforcement. The energy consumed by the aforementioned processes in this phase was considered. The energy values include the consumption of electricity, including that required for operation of machinery and the use of fuels. These values were obtained from the EcoInvent database, which includes previously determined data. After the concrete and reinforcement are produced, they are delivered to the construction site, where the reinforced concrete floor slab is constructed. The construction site was assumed to be located near Zagreb. The concrete is transported from the concrete plant using a truck pump over an average distance of 30 km. The reinforcement is transported to the construction site by train from Italy. The energy required for concrete placement (use of pump and vibrating machine) was taken from [17], whereas human labour was not considered owing to the lack of data. To further promote and increase the recycling of construction and demolition waste and determine the ecological impact of the management of demolition waste after the EoL of a construction product, three different scenarios were considered, as presented in Table 3. According to the *Waste Catalogue Ordinance* (Official Gazette 90/15) [18], the removal of a reinforced concrete floor slab generates two types of demolition waste: waste code 17 01 *concrete, bricks, tiles/tiles and ceramics,* that is, *17 01 01 concrete a*nd waste code 17 04 *metals (including their alloys)*, that is, 17 04 05 *iron and steel*. The total amount of construction and demolition waste generated in Croatia in 2020 was estimated to be 1,399,192.7 t [19]. According to the calculation method established in the Commission Decision 2011/753/EU [20], the recovery rate of construction and demolition waste in Croatia in 2020 was 60 %, which is lower than the target recovery rate established in the Waste Framework Directive (2008/98/EU) [4]. Scenario I assumes that all demolition waste is recycled (100 %) for waste code 17 04 05 and 60 % for waste code 17 01 01, whereas the rest is l andfilled. Scenario II, the worst-case scenario (100 % disposal for waste code 17 01 01), was intended to demonstrate the environmental impact of concrete disposal. Scenario III represents the target value for the 100 % recycling of concrete and steel reinforcement. In the modelling of EoL, the cutoff method was used, which was also used in [21]. This means that the environmental impacts of all stages, from raw material production to disposal of non-recyclable waste, are included in the system, whereas the environmental impacts of recycling are excluded from the system because they are considered to impact the next product system. The use and maintenance phases of the reinforced concrete floor slabs were not considered in this analysis. In addition, for Scenario I, the impact of the transportation distance between the construction site and sorting facility for recycling construction and demolition waste was analysed and two different transport distances were compared (50 and 150 km) because recycling facilities are often not located near demolition sites.

Table 5. Overview of the considered impact categories according to the method CML 2002 [22, 23]

Impact category	Category indicator	Cause	Unit
Abiotic depletion	Abiotic depletion potential, ADP	Use of natural resources (water, metals, etc.)	kg Sb eq
Abiotic depletion (fossil fuels))	Abiotic depletion potential (fossil fuels), ADP-FF	Use of natural resources (fossil fuels)	MJ
Climate changes	Global warming potential for a period of 100 years, GWP100a	Effect of greenhouse gases caused by anthropogenic activity	kgCO$_2$ eq
Ozone depletion	Ozone layer depletion, ODP	Depletion of the ozone layer caused by different gases	kgCFC11 eq
Human toxicity	Human toxicity potential, HTP	Impact of emissions of harmful substances and chemicals on people causing a negative impact on health (carcinogenicity, etc.)	kg 1,4-DP eq
Fresh water aquatic ecotoxicity	Fresh water aquatic ecotoxicity potential, FAETP	Impact of emissions of harmful substances and chemicals on terrestrial, freshwater, marine, and aerial ecosystems causing increased mortality, mutations, reduced reproduction, changes in behaviour, etc.	kg 1,4-DP eq
Marine aquatic ecotoxicity	Marine aquatic ecotoxicity potential, MAETP		kg 1,4-DP eq
Terrestrial ecotoxicity	Terrestrial ecotoxicity potential, TETP		kg 1,4-DP eq
Photochemical ozone formation	Formation potential of tropospheric ozone, POCP	Photochemical formation of ozone and other reactive oxygen compounds in the troposphere from VOC and NOx emissions under the influence of light	kg C$_2$H$_2$ eq
Acidification	Acidification potential, AP	Acidification of soil and water systems by excessive use of anthropogenic compounds such as SO$_x$, NO$_x$, HCl, H$_2$SO$_4$	kg SO$_2$ eq
Eutrophication	Eutrophication potential, EP	Deposition of nitrogen and/or phosphorus in freshwater ecosystems	kgPO$_4^{3-}$ eq

2.3. Life cycle impact assessment

LCIA is a part of LCA in which information from the elementary flows of the life cycle inventory is transformed into specific environmental impact categories and category indicators. Unlike the other three phases of LCA, in practice, LCIA is largely automated by LCA software and users of the software should have good knowledge of its principles to ensure a high-quality interpretation of the results. The software used in this case was SimaPro version 9.3. The LCIA phase assesses the environmental contribution of each elementary flow from the LCI inventory using impact categories [7]. The first step in the LCIA phase is to select the environmental impact categories considered as part of the overall LCA. For LCIA, impacts are defined as the negative consequences of system inputs and outputs on human health, plants, animals and the future availability of natural resources. The impact categories described in this study for which the LCA was performed are listed in Table 5. The impact category is a classification that identifies environmental issues of significant concern to which the results of the LCIA can be assigned. For each impact category listed in Table 5, environmental and anthropogenic causes are indicated.

The second mandatory step in LCIA is classification, that is, assigning LCI results to impact categories according to their known potential impacts. An elementary flow from the LCI can contribute to several impact categories; for example, CO_2 emissions to the air are assigned to climate change, or water consumption is assigned to the water use impact category [22]. The characterisation step in LCA involves the calculation of category indicator results that quantify the contributions of inventory flows to different impact categories. In this step, conversion factors, that is, characterisation factors created based on scientific analyses, are used. These factors translate the values obtained in the LCI analysis phase into representative indicators, or represent the contribution per quantity of an elementary flow to a specific environmental impact (category). There are two different types of impact indicators in accordance with [22]: midpoint and endpoint. In general, the midpoint and endpoint impact indicators represent two different approaches to selecting an impact indicator: a problem-oriented approach and a damage-oriented approach along the cause–effect chain. In the problem-oriented approach, quantitative modelling occurs at a relatively early stage and does not focus as much on environmental damage as in the damage-oriented approach. The endpoint indicators show the actual environmental damage with higher uncertainties at three levels: effects on human health, biodiversity and resource scarcity. In this study, the midpoint impact indicators were used according to the CML 2002 method. The output data, that is, the results of the analysis within the SimaPro software, were calculated according to the method used and the representative environmental indicators were presented in the form of diagrams or tables for each of the four LCA steps.

3. Interpretation of results

Table 6 lists the individual results of the LCA per impact category of the reinforced concrete floor slab for the three different scenarios, whereas Figure 3a), b) and c) show the contribution of each life cycle phase to the total life cycle by individual impact categories. A comparison of the environmental impacts of the different waste management scenarios (scenarios I, II and III) is shown in Figure 3d). Based on the results in Table 6, for all three waste scenarios, phases A1–A3 made the largest contribution to the environment for all impact categories (except for the FAETP scenario impact category II). The visual representation in Figure 3 makes this clearer and easier to understand. The reason for this is cement production, excavation of coarse aggregates and sand from nature and the use of iron ore as a raw material for reinforcement production. In addition, the authorsi [11] recommended a concrete mix for the production of 1 m^3 of concrete with a relatively high water–cement ratio (0.605). However, lowering this ratio could potentially reduce the environmental impact of phases A1–A3. In almost all impact categories for the considered system Scenario I, phases A1–A3 made the largest contribution, ranging from 58.74 % (impact category: ozone depletion, ODP) to 90.83 % (impact category: photochemical oxidation, POCP). In Scenario III, the contribution of phases A1–A3 was even more significant, especially for the categories related to toxicity (HTP: 93.15 %, FAETP: 97.4 %, MAETP: 96.07 % and TETP: 89.36 %) and the ADP category indicator (90.41 %) for the use of natural resources and water. The product life cycle, which includes modules A1–A3, concerns the supply of raw materials, processing and transportation to production facilities and manufacturing. It was expected that the contribution of these modules to the environmental impact would be extremely large because of the acquisition of resources and their processing, which have a large impact on the environment in the first place [24, 25], which has also been demonstrated in this case. Phases A4–A5 include the transportation of construction products to the installation site and the actual installation of the reinforced concrete floor slab. They address the environmental impacts of transportation and energy consumption required to operate the machinery during installation. The impact categories with the largest contributions in phases A4–A5 for Scenario I were ozone depletion (ODP, 9.08 %), abiotic depletion - fossil fuels (ADP-FF, 5.82 %) and acidification (AP, 5.13 %). There were no significant differences in the impact categories for the A4–A5 phases in scenarios II and III compared with those of Scenario I.

From the results in Table 6, it can be observed that, as expected, Scenario II had higher values in all the observed impact categories, that is, a significant impact on the environment. An increase in the recycling of demolition waste contributes significantly to the reduction of toxic impacts on soil, water and humans. The values for HTP, FAETP, TETP and MAETP increase when demolition waste is disposed of in landfills (Scenario II). This was also observed during eutrophication. This must be highlighted in the case of uncontrolled disposal in illegal landfills (Figure 1), which has a negative impact on the environment and human health. Under Scenario II, the

Table 6. Environmental impact assessment

Impact category	Unit	Concrete	Reinforcement	A1-A3	A4-A5	End of life scenario		
						SCENARIO I	SCENARIO II	SCENARIO III
ADP	kg Sb eq	0,14475651	0,17645108	0,32120759	0,009881355	0,021012126	0,023985391	0,01903
ADP-FF	MJ	218850,7	331169,31	550020,01	43721,45835	144665,9155	174275,8415	124926
GWP100a	kgCO$_2$ eq	55071,269	31887,224	86958,493	3016,16349	6701,471537	7453,763237	6199,944
ODP	kgCFC11 eq	0,001653489	0,001720816	0,003374305	0,000522114	0,001702541	0,002017075	0,001493
HTP	kg 1,4-DP eq	10437,592	42580,879	53018,471	1142,433611	16812,46506	38814,26606	2144,598
FAETP	kg 1,4-DP eq	7841,0345	67409,368	75250,4025	628,654546	35037,54386	86006,33886	1058,347
MAETP	kg 1,4-DP eq	14377256	83780623	98157879	1248593,669	34083548,23	82007166,23	2134470
TETP	kg 1,4-DP eq	44,33091	59,139936	103,470846	3,6000872	7,625547857	8,837892557	6,817318
POCP	kg C$_2$H$_2$ eq	5,8508979	15,255837	21,1067349	0,460033969	1,539221468	2,007485668	1,227045
AP	kg SO$_2$ eq	111,12009	114,10954	225,22963	14,33112091	35,51929962	40,61704162	32,12081
EP	kgPO$_4^{3-}$ eq	37,838173	59,488952	97,327125	3,66391501	37,34047848	82,74636248	7,069889

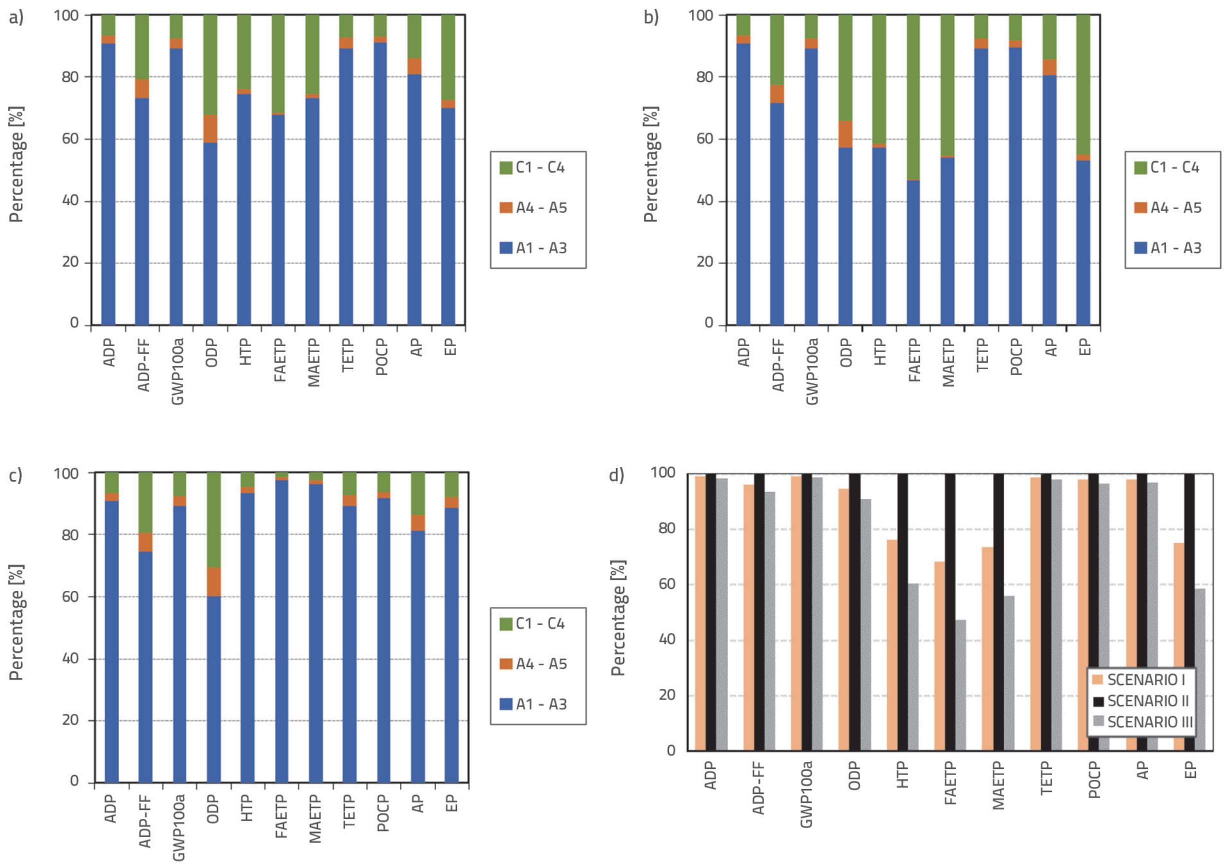

Figure 3. Contribution of each module to the total environmental impact for: a) Scenario I; b) Scenario II; c) Scenario III; d) comparison of environmental impacts according to different waste management scenarios

toxicity values for humans, drinking water and soil (HTP, FAETP and TETP) increased by 130 %, 145 % and 140 %, respectively, while eutrophication values increased by 122 % compared to those under Scenario I. Significant reductions in the impact category of toxicity to humans, HTP (87 % reduction), drinking water, FAETP (97 %) and eutrophication, EP (81 %), were observed when using Scenario II for demolition waste (100 % recycling), as shown in Figure 3.c).

The impact of the distance of the facility or recycling site from the construction site is shown in Figure 4 for Scenario I, where the recycling facility was 50 or 150 km away. A significant decrease in all category indicators is observed when the recycling facility is closer to the construction site, indicating the need to recycle demolition waste close to the demolition site.

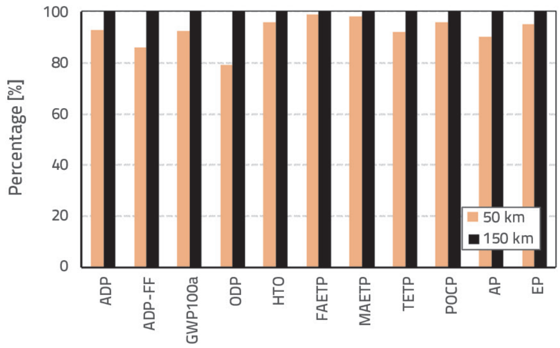

Figure 4. Impact of transport on the overall life cycle for Scenario I by individual impact categories

This is consistent with the conclusions of [24], in where long distances between the demolition site and recycling facility are not recommended. Transportation is important in demolition waste management because of the large quantities involved. The authors [25] suggest the use of small mobile facilities and strategic planning for the construction of sorting and recycling facilities at the national level to reduce illegal dumping. In addition, the analysis of different scenarios for the management of demolition waste caused by earthquakes [26] has shown that it is best to process the waste at its place of origin, if possible.

One of the key elements for the wider application of the LCA methodology in the future is a high-quality inventory database for the production of materials, transportation and installation and, in particular, a database for the management of construction and demolition waste adapted to the geographical area. The quality of the environmental impact assessment results depends largely on the quality of the inventory data. The use of LCA can provide broader knowledge of the individual impacts of waste management methods, with the goal of preventing or reducing waste generation, improving recovery efficiency and increasing the recycling and use of recycled materials. LCA provides an opportunity to analyse the environmental aspects of different waste management strategies and allows a comparison of the potential impacts of these options.

4. Conclusions

In this study, an LCA of a reinforced concrete floor slab was conducted by comparing three waste management scenarios based on the demolition of the concrete floor slab at the end of its service life. Scenario I is based on the current construction and demolition waste recycling percentages in Croatia, Scenario II is based on 100 % landfilling of construction and demolition waste and Scenario III represents an ideal situation in which 100 % of the construction and demolition waste is recycled. The percentage of recycling has a large impact on the environment. In all impact categories, the values for Scenario III were lower. For all three scenarios, phases A1, A2 and A3 are defined as critical points for the impact categories AD, ADP-FF, GWP100a, TETP, POCP and AP (above 70 %) in the life cycle of the reinforced concrete floor slab, which means that the extraction of raw materials, their transportation and the production of concrete and reinforcement have the largest environmental impacts. The reason for this is certainly the amount of raw materials taken from nature; the production of cement, concrete and reinforcement; the harmful gases produced during their processing; and the long transport routes of raw materials to the final production site. One potential strategy for decreasing the carbon footprint during the product stage is to primarily utilise local raw or secondary materials. This helps minimise the distance required to transport raw materials for manufacturing [27]. In the project and design phases, it is necessary to consider the last phase of the life cycle of a building [28] (including the EoL), where the decision on recycling contributes to a healthier environment and the sustainable use of natural resources is one of the basic requirements for buildings [29].

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