EURO POLES

SPUN CONCRETE COLUMNS WITH OUTSTANDING ECOLOGICAL LIFE CYCLE ASSESSMENT

A study by Life Cycle Engineering Experts – LCEE, a consulting company specializing in the sustainability of structures – has shown that spun concrete columns, when compared to composite steel columns, have appreciably more favourable environmental footprints over their entire life cycle. The main reason for this benefit is primarily the special efforts taken during manufacture of the columns. Composite steel columns, owing to their massive steel cores, have considerably more serious environmental impact. The structural design of spun concrete columns, however, occasions significantly less use of materials. In addition to reduced use of materials, positive effects on environmental balance furthermore result from the use of reinforcing steel with a large recycling share, as well as the lack of maintenance for spun concrete poles.

LCEE Life Cycle Engineering Experts GmbH

Life Cycle Assessment: Columns

Environmental comparison of spun-concrete columns and composite steel columns

Commissioned by: Europoles GmbH & Co.KG
Ingolstädter Straße 51
92318 Neumarkt, Germany

Prepared by: LCEE Life Cycle Engineering Experts GmbH
Petersenstraße 12
64287 Darmstadt, Germany

info@lcee.de
www.lcee.de

This project report consists of 16 pages.

Table of contents

Project report: Life cycle assessment of column systems

1 Motivation and background of the study 3

2 Assessment method: LCA acc. to DIN EN ISO 14040 and 14044 4

2.1 The method in general 4

2.2 Phases of a life cycle assessment 5

2.3 Selected life cycle assessment impact categories 6

3 Life Cycle Assessment of two types of columns 9

3.1 Goal and scope of the study 9

3.2 Life cycle impact assessment 11

3.2.1 Results concerning column production 11

3.2.2 Results concerning column use 12

3.2.3 Results concerning column recycling 13

3.2.4 Results concerning the overall life cycle assessment of the columns 13

4 Bibliography 16

1 Motivation and background of the study

Sustainable construction and design reflect the Zeitgeist. The demand for sustainable activity and action will have an impact on all spheres of life and also change the construction sector fundamentally. In this context sustainability refers to the ecological, economical, and technical optimization of building structures in such a manner that natural resources are conserved. An additional objective of sustainable construction in the spirit of sustainability is the minimization of harmful effects on both people and society. In the context of sustainability new opportunities, incentives, and risks arise for every single interest group involved. Companies who react to these newly arising demands at an early stage will be able to secure a leading position in this field.

Europoles product development and marketing has risen to the challenge posed by "sustainability" and has commissioned Life Cycle Engineering Experts GmbH (LCEE) to prepare a life cycle assessment study according to DIN EN ISO 14040 and 14044. The objective of this study is to determine the environmental impacts of two column systems with different designs:

[1] Spun-concrete colums by Europoles
[2] "Geilinger" composite steel and concrete column

Various environmental impact categories, such as Primary Energy Consumption, Acidification Potential and Global Warming Potential, were taken into account when conducting the study which serves the purpose of providing a comparative analysis of the environmental impacts of different columns in building constructions. The life cycle assessment may help product developers to identify untapped potential for improving resource efficiency. The knowledge of the environmental impacts associated with a company's products also enables Europoles to react strategically to the requirements of the market. In a DGNB (German Sustainable Building Council) certification process for buildings, for example, the analysis of the environmental impacts of construction products using the life cycle assessment method will improve the evaluation results. In this context, the improvement amounts to 10% of the environmental impacts. The reason for this is that within the DGNB certification system building products without a product-related life cycle assessment are evaluated using an environmental average value plus a safety margin of 10%. The environmental impacts of the columns mentioned above were compared using data on production and material provided by Europoles.

Both the input parameters of the study and the findings established by the study are described below:

2 Assessment method: Life cycle assessment acc. to DIN EN ISO 14040 and 14044

2.1 The method in general

The method of assessment used for this research project is life cycle assessment in accordance with DIN EN ISO 14040 and 14044 [1] [2]; the purpose of life cycle assessment is to evaluate the environmental aspects associated with a product as well as the potential environmental impacts related to a product.

Here is a definition of life cycle assessment by Allen Astrup Jensen:

> *„Life-Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and material uses and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process, or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; re-use, maintenance; recycling, and final disposal.*
>
> *The Life-Cycle Assessment (LCA) addresses environmental impacts of the system under study in the area of ecological health, human health and resource depletion. It does not address economic considerations or social effects. ... " [3]*

In this context the term "product" may refer to goods (e.g. a building or a column), procedural auxiliary materials (e.g. a lubricant), or services (e.g transport).

According to DIN EN ISO 14040 and 14044, a life cycle assessment consist of the following phases, which are also displayed below in Figure 1:

1. Definition of the goal and scope of the life cycle assessment
2. Life cycle inventory analysis (LCI)
3. Life cycle impact assessment (LCIA)
4. Interpretation

These individual phases are often interdependent and should not be considered separately. The individual steps or phases of a life cycle assessment are explained in detail below.

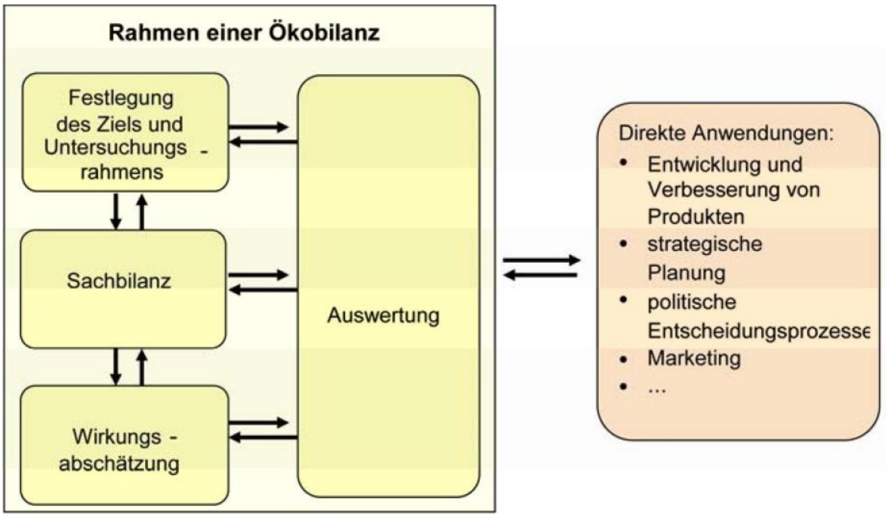

Figure 1: Phases of a life cycle assessment according to DIN EN 14040 and 14044 [2]
[Translation of Figure 1: Life cycle assessment framework – Goal and scope definition – Inventory analysis – Impact assessment – Interpretation – Direct applications:

- Product development and improvement
- Strategic planning
- Public policy making
- Marketing …]

2.2 Phases of a life cycle assessment

According to DIN EN ISO 14040, the first phase of a life cycle assessment (compare Figure 1) consists of two stages, namely the "goal definition" and the definition of the "scope of the study". Here the "goal definition" includes giving reasons for carrying out the life cycle assessment as well as defining the intended audience of the study. The "scope of the study", which is also defined, includes details on the system boundaries, the functional unit, and information on data quality. Here the system boundaries are defined as the technical and geographical coverage of the data, as well as the time-related coverage concerning the time during which the life cycle assessment is drawn up. Ideally, the system boundaries should be selected in such a manner that inputs or outputs at its boundaries will only appear as elementary flows. In order to ensure the comparability of two or more life cycle assessments, a functional unit needs to be specified. A functional unit serves as a reference to which the input and output flows are related. Two life cycle assessments are comparable if they fulfill the same function or serve the same purpose and have identical system boundaries.

In the life cycle inventory analysis to be compiled during the second phase of a life cycle assessment, data on the input and output flows of the product system are collected and quantified. In the life cycle inventory analysis energy and material flows are related to the functional unit. The life cycle inventory analysis forms the basis for the subsequent life cycle impact assessment.

In the "life cycle impact assessment" phase potential environmental impacts are deduced using the data compiled during the life cycle inventory analysis. For this purpose the individual material and energy flows resulting from the life cycle inventory analysis are assigned to specific impact categories that were selected for the study (classification) and weighted according to their contribution to the environmental impact associated with the impact category (characterization). Possible impact categories of a life cycle assessment are listed in section 2.3.

The findings of the study are presented in the final phase of a life cycle assessment, the "interpretation". Furthermore, the quality of the life cycle assessment is evaluated by carrying out a completeness check, a sensitivity check, and a consistency check. Moreover, the consistency of the results with the goal defined in phase 1 as well as the scope of the life cycle assessment are checked. This phase also contains the conclusions, explanation of limitations, and recommendations for a future course of action.

2.3 Selected life cycle assessment impact categories

Environmental impacts are assigned to environmental impact categories in order to be able to ascertain and quantify them. The purpose of the study as well as the goal of the study defined previously should be considered when selecting the impact categories. A selection of environmental impact categories is listed below. Scientifically accepted measuring methods exist for these impact categories. Besides this, they form part of the category "Ecological Quality", one of the main categories of criteria introduced by the Federal Ministry of Transport, Building and Urban Development (BMVBS) within the scope of the "German Seal of Approval for Sustainable Building“ ("Deutschen Gütesiegel Nachhaltiges Bauen").

Global Warming Potential (GWP) [in kg CO_2 eq.]

Global Warming Potential (GWP), measured in kg CO_2 equivalent, is a measure of how much a unit mass of gas contributes to global warming compared to carbon dioxide. A product with a low GWP value causes only low gas emissions contributing to global warming. Gases that need to be mentioned in this context are for example CO_2, CH_4 , N_2O, SF_6, PFC, and HFC.

Their values are expressed in CO_2 equivalent relative to the greenhouse effect of carbon dioxide. Due to the characteristic effect of greenhouse gases and their various atmospheric lifetimes, the Global Warming Potential is a time integral for a certain time horizon. This is why the reference time horizon – 25, 100 or 500 years – must always be given when referring to the category Global Warming Potential. The reference time horizon for this study is 100 years (GWP_{100}).

Ozone Depletion Potential (ODP) [in kg R_{11} eq.]

As the name implies, Ozone Depletion Potential (ODP), measured in R_{11} equivalent, is a measure of the destructive effects of gases on the ozone layer. The ozone layer is the earth's shield against UV radiation and in this way prevents excessive warming of the earth's surface. Consequences of ozone layer depletion include, among others, the growth of tumors in humans and animals as well as photosynthetic disruption in plants.

Photochemical Ozone Creation Potential (POCP) [in kg C_2H_4 eq.]

Photochemical Ozone Creation Potential (POCP), also known as summer smog potential, measured in kg C_2H_4 equivalent, is a measure of how much a unit mass of harmful trace gases, such as nitrogen oxides and hydrocarbons, contributes to the formation of ground-level (tropospheric) ozone in the presence of UV radiation. The human and ecotoxic pollution of the ground-level atmospheric layers caused by this is also called summer smog. Summer smog affects respiratory organs and has a harmful effect on plants and animals. The ground-level ozone concentration is measured in regular intervals at air quality monitoring stations; the data is shown and published in pollution maps.

Eutrophication Potential (EP) [in kg PO_4 eq.]

Overfertiliziation (eutrophication) refers to waters and soils changing from a nutrient-poor (oligotrophic) condition to a nutrient-rich (eutrophic) condition. It is caused by an increase in nutrients, in particular by phosphorous and nitrogen compounds. They can, for instance, enter the environment during the manufacturing of building products but mainly due to combustion emissions being washed out. The resulting change in the availability of nutrients in water, for example, is an accelerated growth of algae, which can among other things lead to fish kill.

Acidification Potential (AP) [in kg SO_2 eq.]

Acidification potential (AP) refers to the effects of acidifying emissions and is therefore a measure for the environmental impacts of acidification of soils and waters. The higher the AP value the higher the risk of acid rain and environmental damage associated with it. The reference compound for calculating the Acidifcation Potential is SO_2 (sulfur dioxide); the effect of other acidifying emissions (e.g. NO_x, H_2S) is given in SO_2 equivalents, a measure of how much the equivalent of a given mass contributes to acidification.

Primary Energy Consumption from renewable sources (PE_E) [in MJ]

The renewable Primary Energy Consumption of a product is the sum of any primary energy from renewable sources (e.g. biomass, solar radiation, geothermal energy, hydropower, and wind energy) which is used in context with the production, use, and disposal of an economic good (product or service), that is the use of which can be attributed to this economic product. A low PE_E value points to a product which used only little renewable energy in the course of production, use, and disposal. The renewable Primary Energy Consumption should always be considered as a part of the total primary energy consumption; that is the sum of renewable and non-renewable primary energy consumption.

Primary Energy Consumption from non-renewable sources (PE_{NE}) [in MJ]

The non-renewable Primary Energy Consumption of a product is the sum of any primary energy from non-renewable primary energy sources which is used in context with the production, use, and disposal of an economic good (product or service); that is the use of which can be attributed to this economic product. A low PE_{ne}value points to a product which used only little renewable energy in the course of production, use, and disposal. Non-renewable primary energy sources include among others hard coal, lignite, crude oil, natural gas, and uranium.

3 Life Cycle Assessment of two types of columns

3.1 Goal and scope of the study

The goal of this study is to determine and compare the ecological profiles of two types of columns using the life cycle assessment method according to DIN EN ISO 14040 and 14044. The study serves the purpose of determining the ecological properties of the columns as well as identifying potential for improvement with regard to the individual products. The findings are intended for in-house research and development purposes of Europoles GmbH & Co.KG and for marketing purposes.

The system boundaries of the examination comprise, as shown in Figure 2, the entire life cycle of a column. Here, the production of the columns is examined, including precursors and upstream chains. Any materials used during the occupancy of the building in which the column is located are examined as well. This includes in particular the renewal of protective coatings on steel surfaces of "Geilinger" columns. The defined period under review is 50 years. The dismantling of the columns and the recycling at the end of the life cycle of 50 years are included as well. Transport was not included.

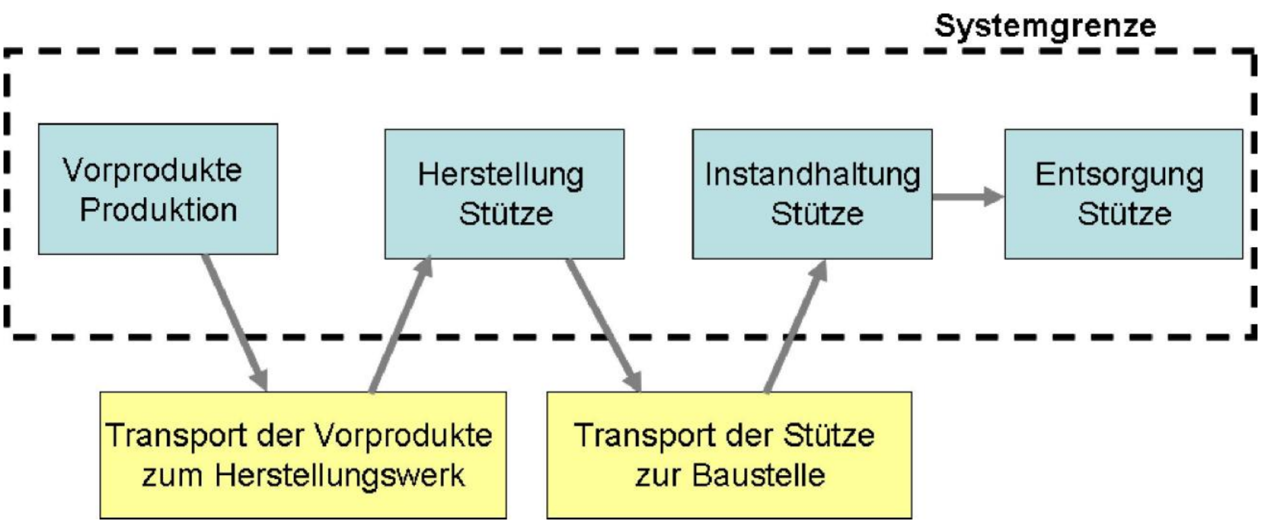

Figure 2: The system boundaries of the study
[*Translation of Figure 2:* System boundaries – Production precursors – Column production – Column maintenance – Column disposal – Transport of precursers to production plant – Transport of column to building site]

In order to ensure comparability of the life cycle assessment of the columns, a column with the following properties was defined as the functional unit of this study:

- Diameter 330 mm
- Length 9430 mm
- Continuous column passing through two floors

The following aspects were not included:

- Load bearing mounting parts

The material and energy flows characterizing each of these individual column systems are allocated to these standard dimensions in the form of materials, auxiliary materials and production processes. The individual details on quantity and weight as well as the details on the individual production processes were provided by the LCA commissioner.

The impact categories included in this study are described in section 2.3; they are also listed below:

- Primary Energy Consumption from non-renewable sources (in MJ)
- Primary Energy Consumption from renewable sources (in MJ)
- Global Warming Potential (in kg CO_2 equivalent)
- Ozone Depletion Potential (in kg R_{11} equivalent)
- Photochemical Ozone Creation Potential (in kg C_2H_4 equivalent)
- Eutrophication Potential (in kg R_4 equivalent)
- Acidification Potential (in kg SO_2 equivalent)

The selected criteria are scientifically and normatively accepted in terms of their assessment methodology and, as already mentioned in section 2.3 , they form part of the main category of criteria within the scope of the "German Seal of Approval for Sustainable Building“, "Ecological Quality". In consultation with the LCA commissioner the presentation and interpretation of further impact categories (e.g. human toxicity) was not included due to their only limited acceptance in the expert community and the limited basis of data available to date.

The modeling of the individual processes and sub-products within the life cycle assessment study as well as the preparation of the life cycle assessment study itself was carried out using the life cycle assessment and database tool GABI 4 by PE International. The data sets available through this software offer the most comprehensive and current database in the German-speaking area. In this way a highly accurate and up-to-date data base is available because the data is maintained regularly. The following section deals with the inputs entering the assessment for the individual product systems; it also provides a compilation of the intermediate products and processes concerning the product system "column".

3.2 Life cycle impact assessment

The life cycle impact assessment of selected impact categories (Primary Energy Consumption from non-renewable and renewable sources, Global Warming Potential, Acidification Potential, Eutrophication Potential, Ozone Depletion Potential, Photochemical Ozone Creation Potential) is carried out using the software and life cycle assessment tool GABI 4 by PE International. In the LCIA, the results of the life cycle inventory analysis are associated with the selected impact categories through the datasets in the database; this is done with regard to all materials used.
The results of the life cycle impact assessment are represented by the tables and charts below.

3.2.1 Results concerning column production

Table 1 contains the results of the life cycle impact assessment concerning the production process of the examined columns.

Impact category	Unit	Column	
		Spun concrete	***Composite steel***
Non-renewable Primary Energy Consumption		12155.2	89336.4
Renewable Primary Energy Consumption		746.8	3515.0
Total Primary Energy Consumption	[MJ]	12902.0	92851.5
Global Warming Potential (GWP)	[kg CO_2 eq.]	978.2	6621.4
Acidification Potential (AP)	[kg SO_2 eq.]	1.958	18.524
Ozone Creation Potential (POCP)	[kg C_2H_4 eq.]	0.292	2.855
Eutrophication Potential (EP)	[kg PO_4 eq.]	0.187	1.757
Ozone Depletion Potential (ODP)	[kg R_{11} eq.]	6.1E-05	1.2E-04

Table 1: Result of the life cycle impact assessment concerning production

The results show that, compared to the spun-concrete column, the composite steel column causes significantly higher environmental impacts in every single impact category. The highest share of environmental impacts can be attributed to the composite steel column's central inner tube made of solid steel. Here, the German standard mixture for steel produced in blast and melting furnaces is used. In this context, the concrete is only of minor importance, also because of the relatively small amount that is used. With regard to the spun-concrete column, it is also steel that affects the environmental impacts most. According to the German standard production mixture, the reinforcement steel used consists mainly of recycled steel; therefore, it features a more positive environmental assessment.

3.2.2 Results concerning column use

During the period of 50 years which were reviewed only the composite steel column requires mainentance work. Due to the steel surface on the outside, corrosion-preventive coating is necessary. In accordance with the "Guide to Sustainable Building" ("Leitfaden Nachhaltiges Bauen") by the Federal Ministry of Transport, Building and Urban Development (BMVBS), a renovation cycle of 18 years was used for the LCA. Thanks to their concrete surface, the spun-concrete columns are maintenance-free and do not cause any environmental imacts during the phase of use. Table 2 contains the results concerning column maintenance.

Impact category	Unit	Column	
		Spun concrete	***Composite steel***
Non-renewable Primary Energy Consumption		0.0	140.1
Renewable Primary Energy Consumption		0.0	2.6
Total Primary Energy Consumption	[MJ]	0.0	142.8
Global Warming Potential (GWP)	[kg CO_2 eq.]	0.0	7.2
Acidification Potential (AP)	[kg SO_2 eq.]	0.0	0.115
Ozone Creation Potential (POCP)	[kg C_2H_4 eq.]	0.0	0.055
Eutrophication Potential (EP)	[kg PO_4 eq.]	0.0	0.002
Ozone Depletion Potential (ODP)	[kg R_{11} eq.]	0.0	4.5E-07

Table 2: Result of the life cycle impact assessment concerning use

3.2.3 Results concerning column recycling

At the end of the assumed life cycle of 50 years the columns are demolished in a controlled manner and fed into the material life cycle via recycling. The results show that the recycling potential of the composite steel column is higher than the one of the spun-concrete column. This is due to the high steel content of the composite steel column which can be recycled. In compliance with the applicable standard, the resulting savings with regard to the production of a new steel product were taken into account. The credits obtained through concrete recycling are not worth mentioning. Table 3 shows the results of the life cycle impact assessment concerning recycling.

Impact category	Unit	Column	
		Spun concrete	***Composite steel***
Non-renewable Primary Energy Consumption		-1238.3	-47492.6
Renewable Primary Energy Consumption		-8.3	-223.4
Total Primary Energy Consumption	[MJ]	-1246.6	-47716.0
Global Warming Potential (GWP)	[kg CO_2 eq.]	-50.1	-3530.8
Acidification Potential (AP)	[kg SO_2 eq.]	-0.242	-12.154
Ozone Creation Potential (POCP)	[kg C_2H_4 eq.]	-0.045	-1.875
Eutrophication Potential (EP)	[kg PO_4 eq.]	0.098	-1.081
Ozone Depletion Potential (ODP)	[kg R_{11} eq.]	2.6E-06	1.2E-04

Table 3: Result of the life cycle impact assessment concerning recycling

3.2.4 Results concerning the overall life cycle assessment of the columns

The overall assessment of the columns during their life cycle shows that, compared to the composite steel column, the environmental impacts caused by the spun-concrete columnare much more favorable. This is mainly due to the materials used for column production. Composite steel columns cause significantly higher environmental impacts due to their solid steel core. These cannot be compensated, not even by the high recycling potential at the end of the life cycle. Because of their design, less material needs to be used for spun-concrete columns in comparison to composite steel columns. This also has a positive impact on the life cycle assessment. In addition to the smaller amount of material used in spun-concrete columns, the use of reinforcement steel with a high percentage of recycled steel also has a positive impact. Another aspect that has a positive influence on the life cycle assessment of spun-concrete columns is the fact that the concrete surface is maintenance-free. Table 4 shows a summary of the results of the life cycle assessment concerning the entire life cycle.

Impact category	Unit	Column	
		Spun concrete	***Composite steel***
Non-renewable Primary Energy Consumption		10916.9	41983.9
Renewable Primary Energy Consumption		738.5	3294.3
Total Primary Energy Consumption	[MJ]	11655.4	45278.2
Global Warming Potential (GWP)	[kg CO_2 eq.]	928.1	3097.8
Acidification Potential (AP)	[kg SO_2 eq.]	1.716	6.484
Ozone Creation Potential (POCP)	[kg C_2H_4 eq.]	0.247	1.035
Eutrophication Potential (EP)	[kg CO_2 eq.]	0.285	0.677
Ozone Depletion Potential (ODP)	[kg R_{11} eq.]	6.4E-05	2.3E-04

Table 4: Environmental impacts of the entire life cycle

In order to illustrate the results of the life cycle assessment, the following figures contain charts showing the individual impact categories.

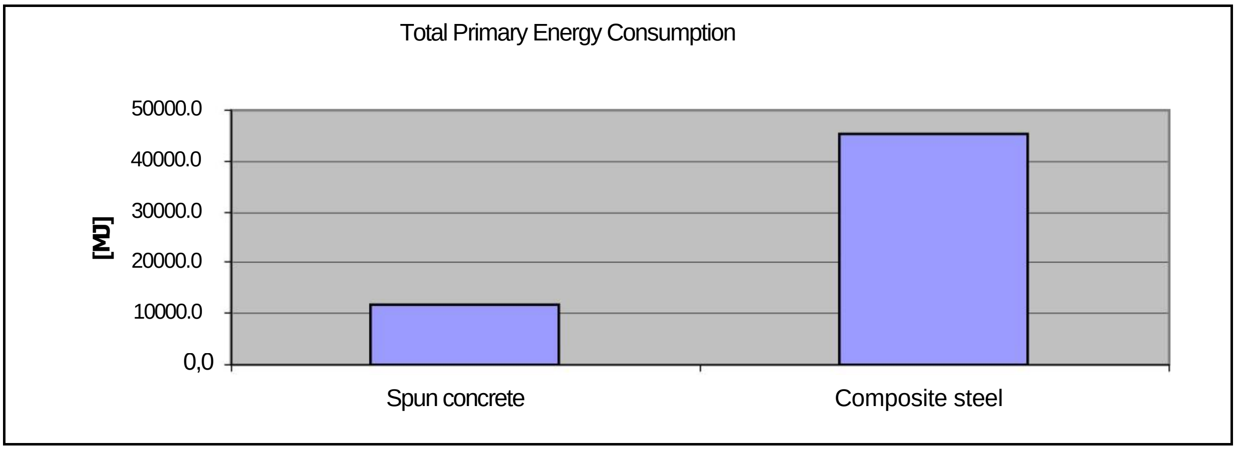

Figure 3: Primary Energy consumed during the entire life cycle

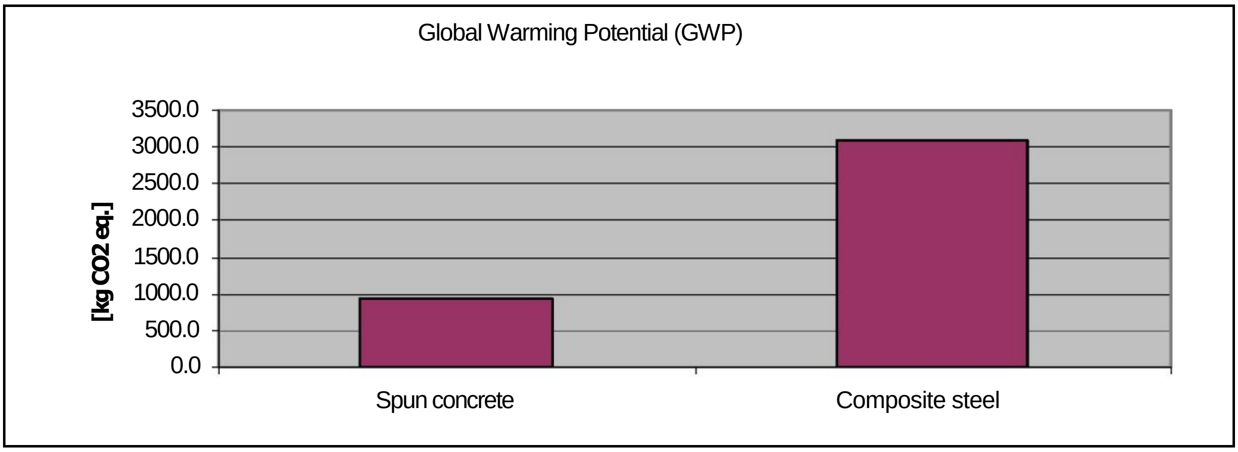

Figure 4: Global Warming Potential during the entire life cycle

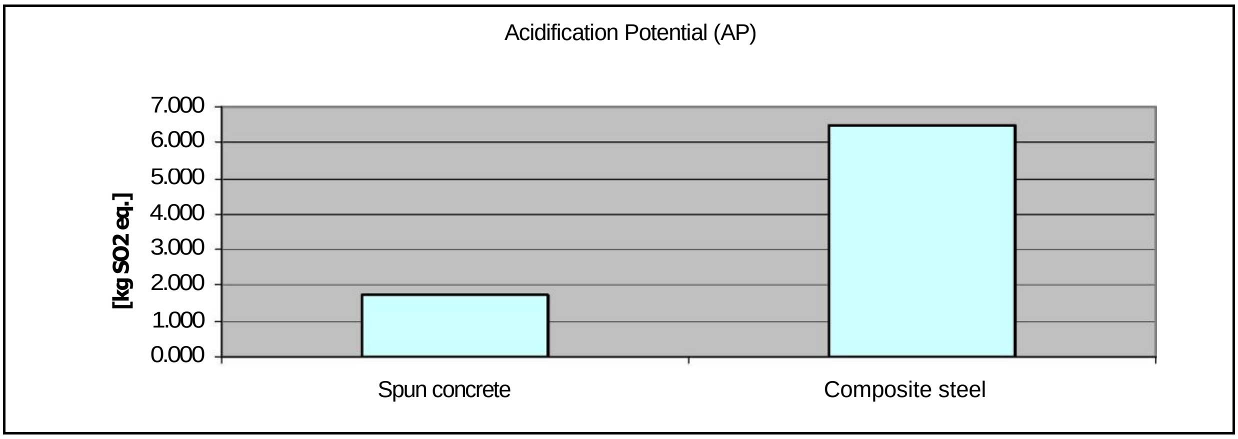

Figure 5: Acidification Potential during the entire life cycle

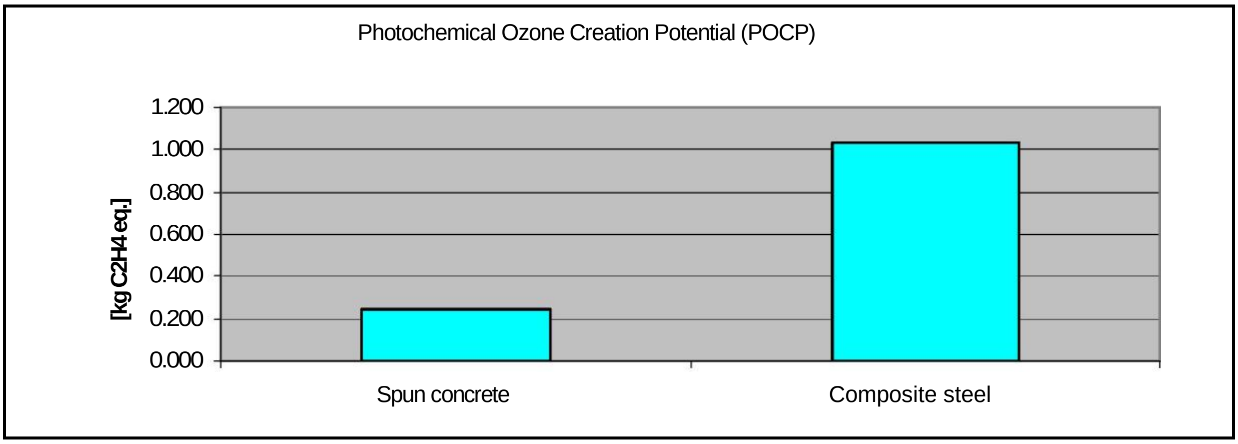

Figure 6: Photochemical Ozone Creation Potential during the entire life cycle

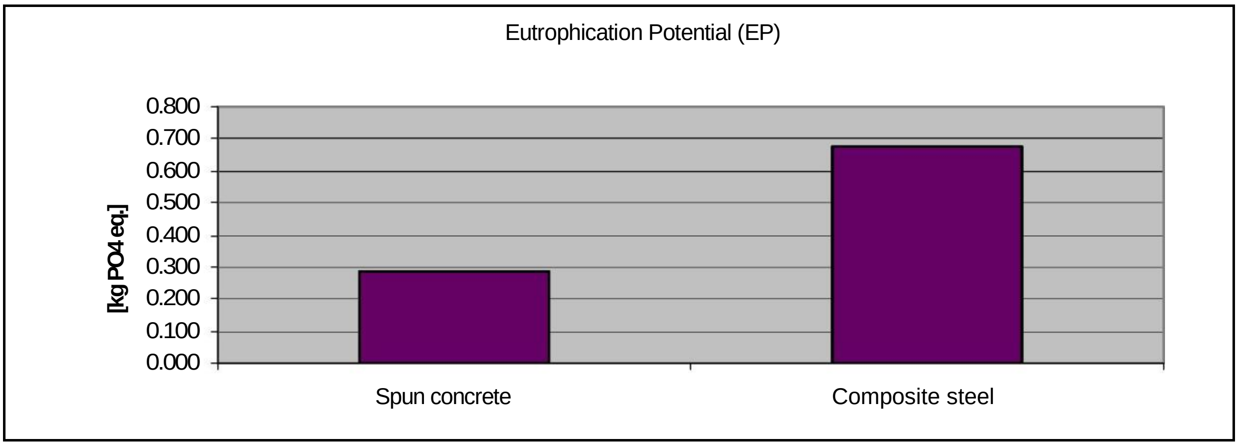

Figure 7: Eutrophication Potential during the entire life cycle

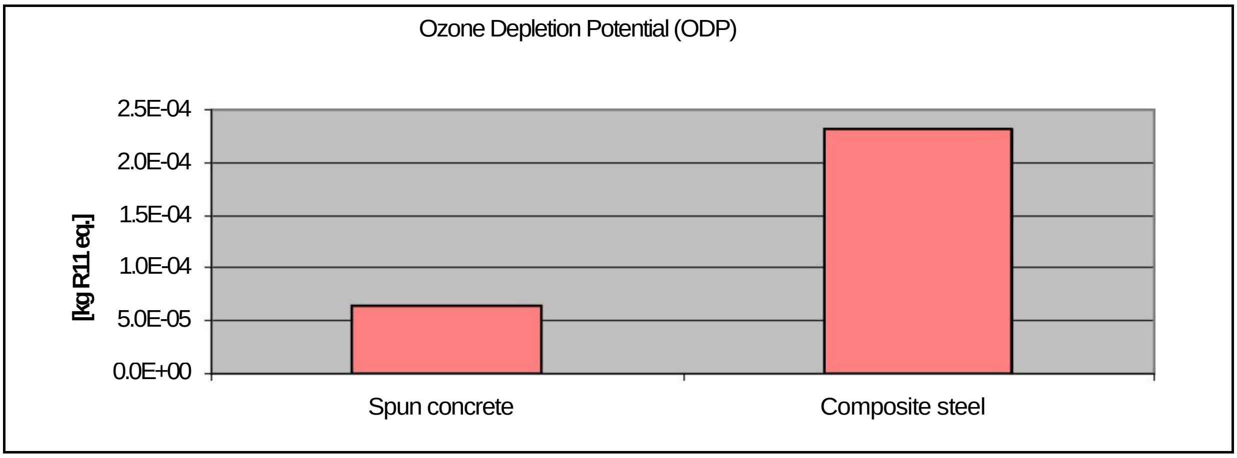

Figure 8: Ozone Depletion Potential during the entire life cycle

4 Bibliography

[1] DIN EN ISO 14040: 2006-10: DIN Deutsches Institut für Normung e.V.: Umweltmanagement - Ökobilanz - Grundsätze und Rahmenbedingungen. (Environmental management - Life cycle assessment - Requirements and guidelines). Beuth Verlag. Berlin, 2006.

[2] DIN EN ISO 14044: 2006-10: DIN Deutsches Institut für Normung e.V.: Umweltmanagement - Ökobilanz - Grundsätze und Rahmenbedingungen. (Environmental management - Life cycle assessment - Requirements and guidelines). Beuth Verlag. Berlin, 2006.

[3] JENSEN, A. A. et al. (2004): Working Environment in Life-Cycle Assessment, Pensacola 2004.

[4] Bundesamt für Bauwesen und Raumordnung (Hrsg.) (Federal Office for Building and Regional Planning (publisher)): Leitfaden Nachhaltiges Bauen (Guide to sustainable building). Berlin, 2001.