CHEMICAL ENGINEERING TRANSACTIONS

VOL. 29, 2012

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Hon Loong Lam, Jiří Jaromír Klemeš

ISBN 978-88-95608-20-4; **ISSN** 1974-9791 DOI: 10.3303/CET1229094

The Environmental Based Selection of Building Materials in Office Building

Miroslav Stajanca, Milan Porhincak*, Adriana Estokova, Peter Kapalo

Technical University of Kosice, Institute of Environmental Engineering, Vysokoskolska 4, 04200 Kosice, Slovakia
milan.porhincak@tuke.sk

The greenhouse effect, ozone depletion, acidification and climate changes in general are well known environmental problems of nowadays. One of the most significant polluters of the environment at all is the building industry. The industry affects the environment in many ways. The construction process and building materials production not only consume the most energy and create huge amount of CO2 emissions, they also create a lot of waste, use non-energy related resources, and are responsible for the overall pollution. Extraction of raw materials to production of building materials, transportations, as well as build-up, operation or demolition of buildings requires massive amounts of energy and it results in huge amounts of greenhouse gasses or acidifying emissions, participates in depletion of ozone layer, eutrophication processes or photochemical ozone creation. The building materials environmental evaluation and its proper selection based on the environmental point of view is one of the significant ways to pollution reduction and energy consumption minimization.

This paper is aimed at the environmental assessment of selected building constructions of office building in Slovak republic and the alternation of building materials in order to reduce the environmental impact of the construction. The selected building has four storeys and a basement. The roof construction of the office building was chosen for the environmental evaluation. Three environmental parameters were taken into the consideration: amount of the greenhouses gases related to the building materials (Global Warming Potential - GWP), amount of the acidification gases (Acidification Potential - AP) and energy consumption regarding the material producing (Primary Energy Intensity - PEI). Data of the particular materials originated from the Austrian LCA database and included the loading of environment within the raw materials extraction, transportation, and material production up to material distribution. Based on this data the values for the whole construction were calculated using MS Excel tool by Createrra. The calculated values of GWP for the original roof construction reached 1,599,340.84 kg CO_2eq, the acidification potential AP was 407.48 kg SO_2eq and the primary energy PEI was calculated up to 544,593.23 MJ.

1. Introduction

At present, the building sector contributes largely in the global environmental load of human activities: for instance, around 40 % of the total energy consumption in Europe corresponds to this sector. It also represents a major target for improvement, and is generally addressed by most environmental policies (Bribián et al., 2009). Buildings themselves also produce approximately 30 % of CO_2 emissions and up to 40 % of total waste (Hájek and Vonka, 2004).
LCA was mainly developed for designing low environmental impact products (De Benedetto and Klemeš, 2009). As products, buildings are special since they have a comparatively long life, they

Please cite this article as: Stajanca M., Porhincak M., Eštoková A. and Kapalo P., (2012), The environmental based selection of building materials in office building, Chemical Engineering Transactions, 29, 559-564

undergo changes often (especially offices and other premises), they often have multiple functions, they contain many different components, they are locally produced, they are normally unique (there are seldom many of the same kind), they cause local impact, they are integrated with the infrastructure, system boundaries are not clear, etc. This implies that making a full LCA of a building is not a straightforward process like for many other consumer products. Assessment of the environmental impacts of buildings and building materials becomes a matter of interest nowadays (Van Ooteghem and Xu; 2012; Eštoková et al., 2011; Arena and de Rosa, 2003,). Ramesh et al. (2010) evaluated the life cycle of buildings in terms of energy use. Ruzicka et al. (2007) concerned on life cycle assessment of structural design of residential house in Czech Republic.
This paper is aimed at the evaluation of the roof construction in the selected office building in the Slovak Republic in relation to the used building materials. The alternation of building materials was designed in order to reduce the negative environmental impact of the evaluated construction.

2. Methodology of assessment

2.1 Evaluated object and roof construction

A four-storey office building located in eastern region of the Slovak Republic was chosen for the environmental assessment in this study (Figure 1).

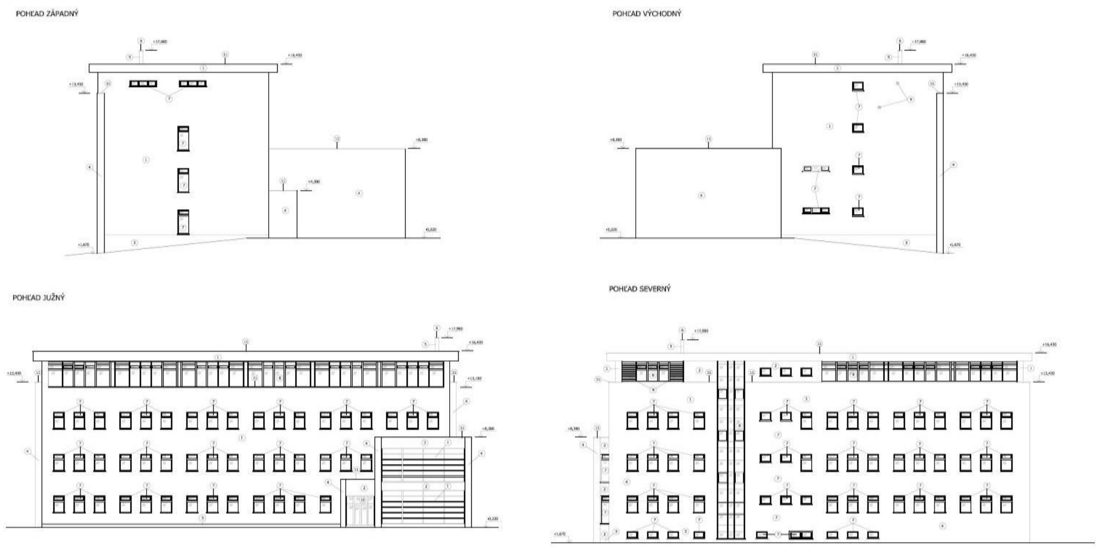

Figure 1: The evaluated office building

The roof construction of the building having area of 794 m^2 was selected for the material composition analysis and building materials environmental evaluation and alternation. The original composition of the evaluated roof construction (Alternative A0) consisted of the layers, materials, thicknesses and weights listed in Table 1.

2.2 Methods of evaluation

Building materials of roof construction were evaluated by the assessment tool based on LCA analysis with using of three main material characteristics: Potential of Energy Intensity (PEI), Global Warming Potential (GWP) and the Acidification Potential (AP). The values of these characteristics included in IBO database of building materials (Waltjen, 2009) were used for the purpose of the assessment. The database values included the data from the first phases of the material life cycle - production phase (cradle-to-gate boundaries).

Table 1: The original roof composition A0

Function of layers	Material of layer	Thickness [mm]	Weight [kg]
Reinforced concrete slab	reinforced concrete (99% concrete, 1% reinforcement)	180	1,088,568.0
Slant layer	polystyrene concrete	430-50	42,577.2
Damp proof course	PVC-P foil	1.5	1,821.6
Protective coating	PE foil	1	352.1
Thermal insulation layer	HPC foamed XPS	160	5716.3
Separating layer	geotextile	0.4	111.1
Ballast layer	crushed stone	50	63,520.0

PEI expresses the material's embodied energy. It is quoted frequently in MJ per mass of material or per square meter of evaluated construction. GWP establishes the relative climate effects of greenhouse gases relating to the building material production. Carbon dioxide, the most important greenhouse gas, is used as a reference parameter with a set GWP value of 1. An equivalent amount of carbon dioxide in kilograms is calculated for every greenhouse-effective substance with this value depending on the gas heat absorption properties and the persistence of the gas in the atmosphere. AP conveys the tendency of the material to contribute to the acidification processes. Acidification is mainly caused by the interaction of nitrogen oxide (NO_x) and sulfur oxide (SO_2) with the air components. Acidification is measured in sulfur dioxide equivalents and an equivalent amount of sulfur dioxide in kilograms is calculated for every acid-effective substance (Waltjen, 2009).
The calculation was based on MS Excel tool (Porhinčák, 2011). The weights, volumes and areas of evaluated materials were used as the program inputs to quantify the Primary Energy Intensity (PEI), Global Warming Potential (GWP) and Acidification Potential (AP) of the roof structure. The potentials of roof construction were calculated by multiplying of material weights with values of material potentials. The alternative materials compositions were calculated the same way as the materials of original construction.

3. Results

The environmental impacts of the original roof construction are summarized in Table 2.

Table 2: The environmental impacts of the original roof composition A0

Function of layers	Material of layer	PEI [MJ]	GWP [kg CO_2eq]	AP [kg SO_2eq]
reinforced concrete slab	reinforced concrete	631,754.63	50,301.05	181.10
slant layer	polystyrene concrete	226,510.70	24,694.78	60.03
damp proof course	PVC-P foil	111,015.77	3,658.32	9.77
protective coating	PE foil	27,114.16	711.31	7.39
thermal insulation layer	HPC foamed XPS	594,500.40	464,739.26	141.19
separating layer	geotextile	1,457.98	43.88	0.37
ballast layer	crushed stone	6,987.20	444.64	7.2
Total		1,599,340.84	544,593.23	407.48

The evaluation of the alternative material compositions was done in order to choose an environmentally acceptable composition of materials with the lowest environmental impacts. Two alternatives (A1 and A 2) were taken into consideration. The selection of the alternative materials was based on the subjective proposal of authors and partially limited due to data absence of several materials in the used database. Comparing the original composition of roof construction A0, the material of separating layer (geotextile) remained the same in both alternatives A1 and A2. The new material composition suggested for A1 is as follows:

- Reinforced concrete slab: reinforced concrete (98.2 % concrete; 1.8 % reinforcement), thickness 160 mm;
- Slant layer: ceramsite concrete, thickness 430-50 mm;
- Damp proof course: EPDM, thickness 1.5 mm;
- Thermal insulation layer: CO_2 foamed XPS, thickness160 mm;
- Separating layer: geotextile, thickness 0.4 mm;
- Ballast layer: gravel 16/32, thickness 50 mm.

The calculated values of Primary Energy Intensity (PEI), Global Warming Potential (GWP) and Acidification Potential (AP) for A1 are summarized in Table 3.

Table 3: The environmental impacts of A1 material composition

Function of layers	Weight [kg]	PEI [MJ]	GWP [kg CO_2eq]	AP [kg SO_2eq]
reinforced concrete slab	967,621.2	604,801.95	46,449.69	171.73
slant layer	141,924.0	283,848.00	54,498.82	377.52
damp proof course	1,584.6	179,059.12	5,260.85	30.90
thermal insulation layer	4,827.1	492,368.28	16,605.36	101.85
separating layer	111.1	1,457.98	43.88	0.37
ballast layer	71,460.0	5,716.80	285.84	3.57
∑	1,187,528.0	1,567,252.13	123,144.44	685.95

The material composition of A2 alternative is following:

- Reinforced concrete slab: reinforced concrete (99.1 % concrete; 0.9 % reinforcement), thickness 200 mm;
- Slant layer: polystyrene concrete, thickness 430-50 mm;
- Damp proof course: bitumen aluminum layer, thickness 4 mm;
- Thermal insulation layer: CO_2 foamed XPS, thickness 160 mm;
- Separating layer: geotextile, thickness 0.4 mm;
- Ballast layer: macadam, thickness 50 mm.

The calculated values of environmental characteristics and material weights for A2 building material composition are listed in Table 4.

Table 4: The environmental impacts of A2 material composition

Function of layers	Weight [kg]	PEI [MJ]	GWP [kg CO_2eq]	AP [kg SO_2eq]
reinforced concrete slab	1,209,546.0	674,939.69	54,805.37	194.50
slant layer	42,577.2	226,510.70	24,694.78	60.03
damp proof course	4,225.6	237,477.82	6,760.93	44.37
thermal insulation layer	4,827.1	492,368.28	16,605.36	101.85
separating layer	111.1	1457.98	43.88	0.37
ballast layer	63,520.0	6,987.20	444.64	7.62
Total	1,324,807.0	1,639,741.68	103,354.96	408.75

The comparison of the total environmental impacts of evaluated alternatives (A0 – A2) is illustrated in Figure 2.

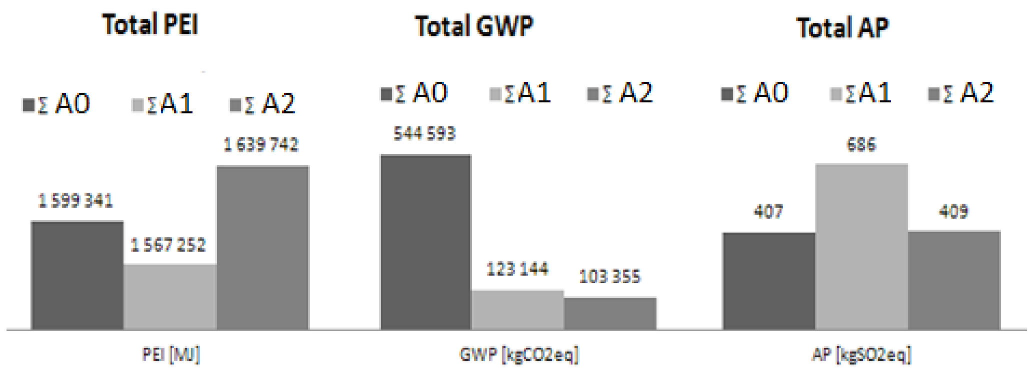

Figure 2: The comparison of the environmental parameters of the original and alternated material compositions of the roof construction

Both the increase and the decrease of the environmental parameters values have been reached by the alternation in material composition of roof evaluated. As it is seen in Figure 2, the material composition of the A1 alternative is the best in terms of the primary energy point of view, but the worst in terms of the acidification effect. The percentage of total calculated values for the alternatives evaluated is summarized in Table 5.

Table 5: The percentage of total PEI, GWP and AP

Material composition	PEI [MJ]	GWP [kg CO_2eq]	AP [kg SO_2eq]
A0	100 %	100 %	100 %
A1	97 %	22.61 %	168.55 %
A2	102 %	18.98 %	100.49 %

The original composition A0 is representing by 100 % for all characteristics. The global warming potentials (GWP) have been significantly decreased for both A1 and A2 alternatives. On the contrary, no decrease was detected in case of the acidification potentials calculated for the A1 and A2 material compositions. Primary energy has been just slightly changed: both increase and decrease were calculated for the alternatives A1 and A2, respectively.
Comparing the alternatives A0 and A1, the value of PEI has been decreased by 3 %, the GWP decrease has been calculated more than by 73 % in case of A1 alternative. On the other hand, the AP value has been increased by 68.55 % and was calculated the most negative of all material compositions evaluated.
The alternative A2 has achieved the lowest value of GWP, decreasing more than by 81 % compared to the A0 material composition. The values of other two characteristics PEI and AP were a little higher than those of the original construction.

4. Conclusion

Summarising the results of the study, the alternation in material composition led to the reduction (global warming potential) as well as to the increase (acidification potential) of the environmental parameters evaluated. The more detailed approach in building material selection together with the multicriterial analysis is of importance in our further study.
Evaluation of the impacts not only building materials but construction at all, has the importance of maintaining both environmental quality and human health. On the base of determining the environmental impacts of materials is then possible the materials with the most negative impacts

replaced by more environmentally friendly materials. Already the use of recycled materials, even in small amounts, in some cases leads to a significant reduction in overall construction impacts on the environment.

Acknowledgments

The research was supported by the project NFP 26220120037 Centre of excellent integrated research of the progressive building structures, materials and technologies and supported from the European Union Structural funds.

References

Arena A.P., de Rosa C., 2003, Life cycle assessment of energy and environmental implications of the implementation of conservation technologies in school buildings in Mendoza-Argentina, Building and Environment, 38, 359-368.

De Benedetto L., Klemeš J., 2009, The Environmental Performance strategy map: LCA based strategic decision making, Chemical Engineering Transactions, 18, 427-432, DOI: 10.3303/CET0918069.

Eštoková A., Porhinčák M., Ružbacký R., 2011, Minimization of CO2 emissions and primal energy by building materials´ environmental evaluation and optimization, Chemical Engineering Transactions, 6, 53-62, DOI:10.3303/CET1125109.

Porhinčák M., Eštoková A., Vilčeková S., 2011, Comparison of environmental impact of building materials of three residential buildings, Pollack Periodica, 6, 53-62.

Ramesh T., Prakash R., Shukla K.K., 2010. Life cycle energy analysis of buildings: An overview, Energy and Buildings. 42, 1592-1600.

Růžička J., Fiala C., Lupíšek A., Mukařovský J., Vonka M., 2007, Environmental and Life Cycle Assessment of Structural Design of Residential House - Case Study, CESB 07 Conference, Prague 2007.

Van Ooteghem K., Xu L., 2012, The life-cycle assessment of a single-storey retail building in Canada, Building and Environment, 49, 212-226.

Hájek P., Vonka M., 2004, Environmental Analysis of Residential Buildings – Life Cycle Assessment, Regional Central and Eastern European Conference on Sustainable Building - Sustainable Building 2004, Warsaw 2004, pp. 73- 74,

Zabalza Brigian I. et al., 2009, Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification, Building and environment, 44, 2510 – 2520.

Waltjen T. 2009, Passivhaus-Bauteilkatalog. Details for Passive Houses, Okologisch bewertete Konstruktionen. A Catalogue of Ecologically Rated Constructions. Vienna, Springer., Austria.