CHEMICAL ENGINEERING TRANSACTIONS

VOL. 52, 2016

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Peng-Yen Liew, Jun-Yow Yong, Jiří Jaromír Klemeš, Hon Loong Lam

**ISBN** 978-88-95608-42-6; **ISSN** 2283-9216

DOI: 10.3303/CET1652104

# Evaluation of Architectural and Environmental Aspects of Passive House

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In Europe, 30 – 40 % of the current total energy demand and approximately 44 % of the total material use are due to the building sector which is a significant percentage of the total environmental load of human activities (Desideri et al. 2014). That is why the European Union and its members agreed on lowering overall energy consumption in each sector by the law.
Construction sector and buildings are responsible for 40 % of energy consumption and 36 % of $CO_2$ emissions in the EU. Currently, about 35 % of the EU's buildings are over 50 y old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5 % to 6 % and lower $CO_2$ emissions by about 5 %.

## 1. Introduction

Passive house is a term known very well to engineers and architects all over the world. In these times of minimizing an energy loads and negative emissions, passive houses (or even net-zero houses, positive houses) are one of the best ways to meet European "20-20-20" targets (Energy Efficiency Directive 2012/27/EU). The main topic of this paper is to create an assessment of a passive house, constructed in Kosice, Slovakia. The passive house was built taking in account architectural, environmental and constructional requirements of today´s euro codes. The passive house was evaluated from two points of view. First, software assessment. The passive house critical details were re-drawn to two-dimensional heat transfer PC software. It was observed how the passive house critical details perform (heat flux, temperature distribution, and surface temperatures).
Also, environmental indicators were calculated using the Life Cycle Assessment method (LCA), such as embodied energy (EE – energy used for acquiring raw material, manufacture and its transport), $CO_2$ emissions ($ECO_2$ – global warming potential GWP) and $SO_2$ emissions ($ESO_2$ – acidification potential AP). Results of these measurements are displayed in numbers as well as in graphic figures.

## 2. Methods

Environmental indicators of envelope structure were calculated by the LCA (Life Cycle Assessment) method within the boundary ''cradle to gate''. The system boundaries of this analysis include the following phases: excavation, manufacture and transport. LCA is a standardised tool used to assess and report relevant environmental impacts of a product's life cycle. The LCA framework is interpreted by international standards, ISO 14040—44 (Benedetto et al., 2009). Estimated in this study are life-cycle assessment components such as EE, global warming potential and acidification potential.
Two-dimensional heat transfer PC software (AREA) was used to illustrate surface temperatures of assessed constructions in building. Temperature boundaries were set for Kosice´s climate (Kosice´s climate date are a part of AREA software library) as well as relative humidity. Thermo-physical parameters are calculated for

Please cite this article as: Sedlakova A., Turcsanyi P., Vilcekova S., Burdova E. K., 2016, Evaluation of architectural and environmental aspects of passive house, Chemical Engineering Transactions, 52, 619-624 DOI:10.3303/CET1652104

Slovak climate conditions (STN EN 730540) : $\theta_e$- outdoor air temperature (-13 °C); $\theta_i$- indoor air temperature (20 °C); Rh- relative air humidity outdoors (84 %) and Rh- relative air humidity indoors (50 %).

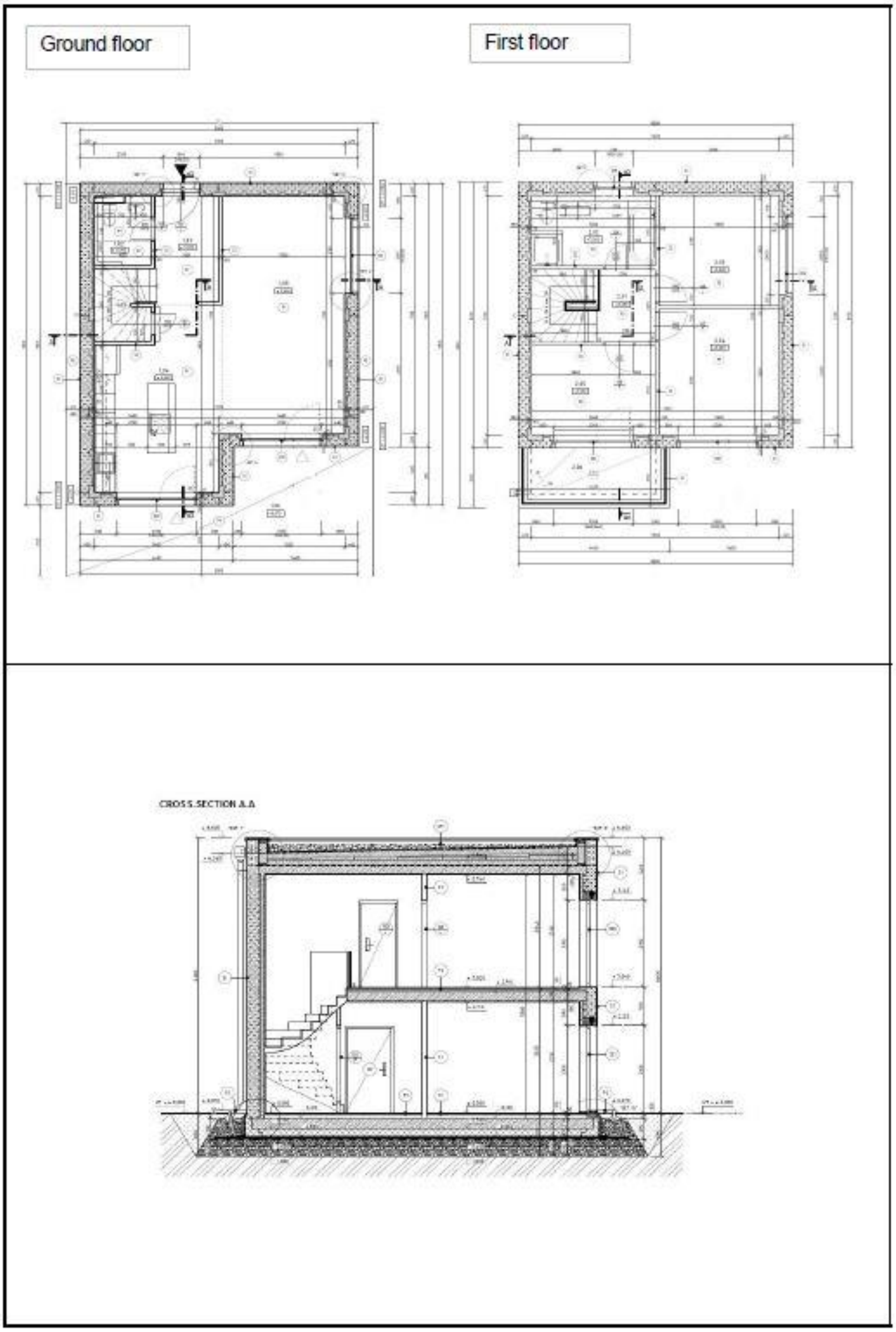


*Figure 1: Ground floor, first floor and cross-section*

## 3. Results and discussion

A) Thermo-physical evaluation

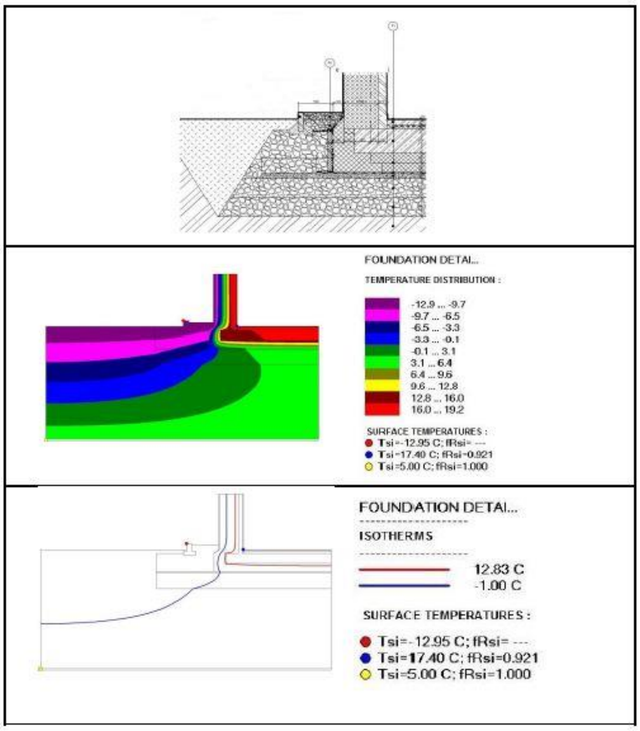


*Figure 2: Thermo-physical evaluation of foundation detail in AREA Software*

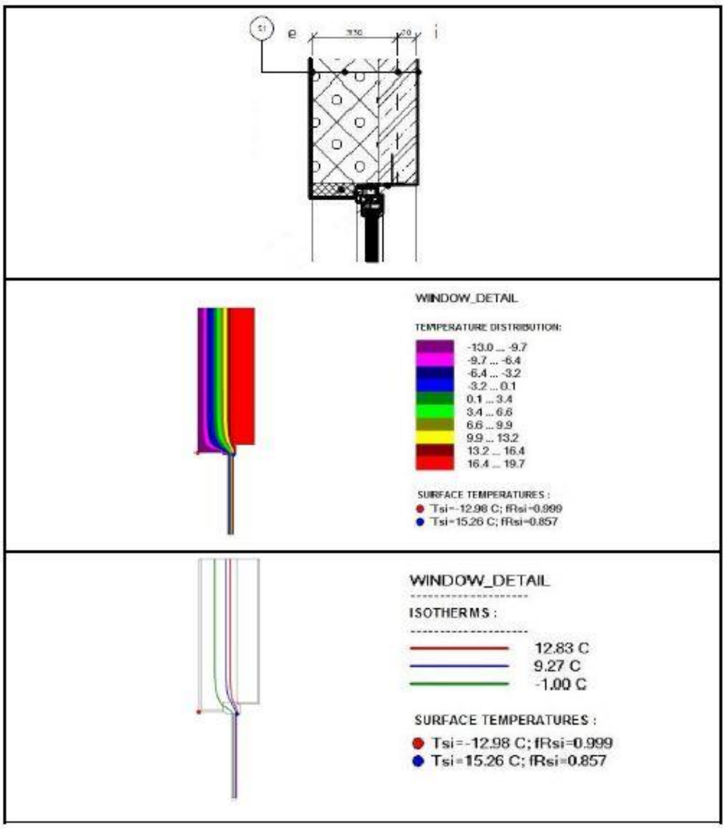


*Figure 3: Thermo-physical evaluation of window detail in AREA Software*

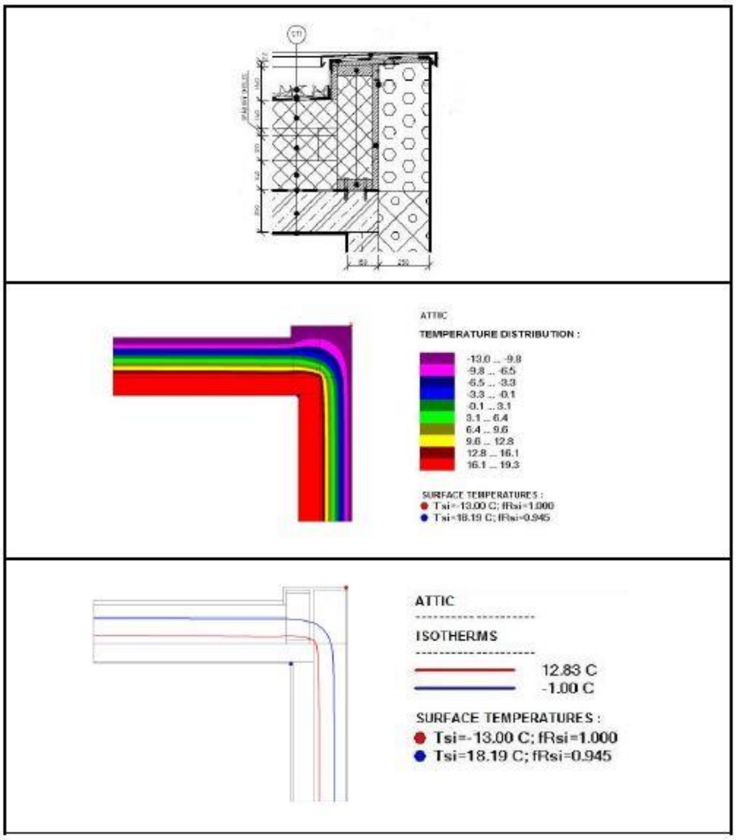


*Figure 4: Thermo-physical evaluation of attic detail in AREA Software*

Thermo-physical evaluations using two-dimensional AREA Software on chosen critical details have shown expected results, as every construction have been designed and constructed according to newest EU Directives. Risk of critical surface temperature (12.83 °C) and dew point temperature (9.27 °C) occurring has been successfully eliminated.

B) Environmental evaluation

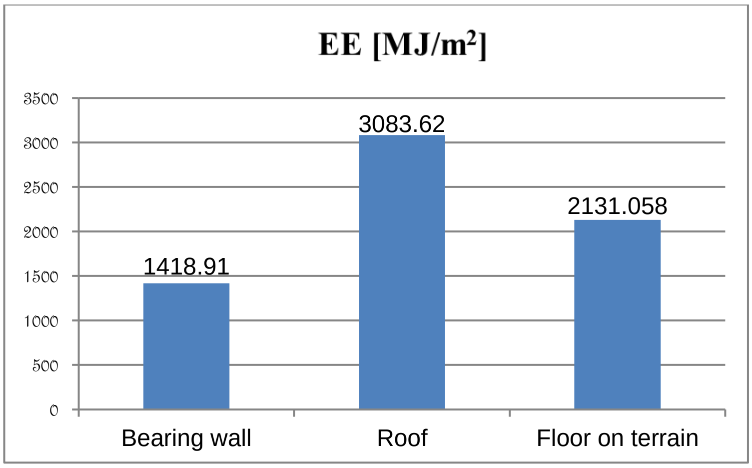


*Figure 5: Embodied energy of building envelope constructions*

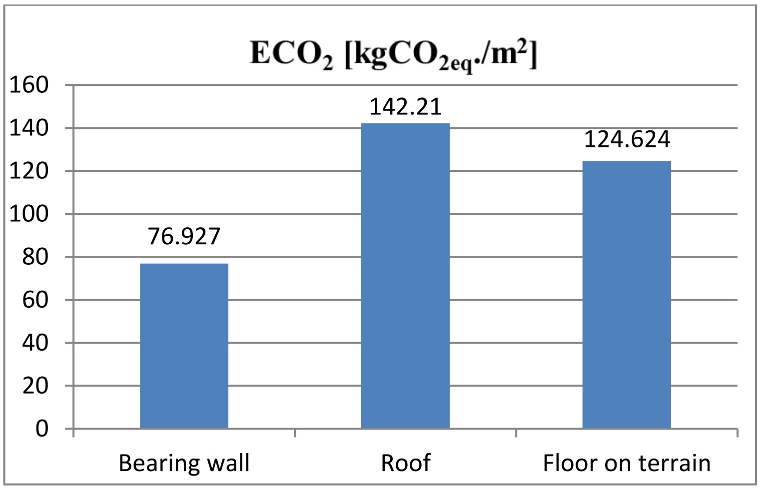


*Figure 6: $CO_2$ emissions of building envelope constructions*

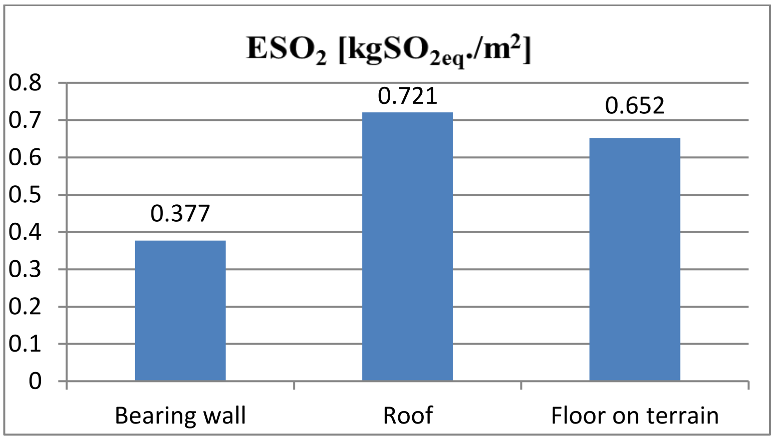


*Figure 7: $SO_2$ emissions of building envelope constructions*

Many studies deal with the environmental evaluation of building materials and compositions as well as whole buildings. The results can be compared and discussed. A study (Sedláková et al., 2015) is focused on analysis of material solutions for design on construction details of foundation. Another study (Sedláková et al., 2015) is oriented on evaluation of structures design concept of lower structure from embodied energy and emissions. The results demonstrate that according to the environmental profiles, reduction of EE by 5 – 42.89 %, of $CO_2$ by 22.75 – 84.76 %, of $SO_2$ by approximately 2.22 – 18.54 % in comparison with other alternatives is possible. Study (Vilčeková et al., 2015) is focused on analysis and identifying the environmental quality of material compositions of exterior walls. The determined values of the environmental impacts of the best alternative of structure with foam glass insulation were 839.2 MJ/$m^2$, 361.429 $kgCO_{2eq}$ and 0.200418 $kgSO_{2eq}$ for embodied energy, $CO_2$ emissions and $SO_2$ emissions. Study (Krídlová Burdová et al., 2014) investigated 4 various exterior wall material compositions. The environmental evaluation results and environmental profiles of wall assembly alternatives shows that the alternative with EPS thermal insulation with graphite achieved the lowest values of EE, $ECO_2$ and $ESO_2$.This alternative of exterior wall ensured the highest reduction of EE by 10 % - 37 %, of $CO_2$ by 2 % - 14 % and of SO2 by approximately 10 % - 57 % in comparison with the other mentioned alternatives.

## 4. Conclusions

The goal of this paper was to asses a passive house from two points of view. Thermo-physical and environmental. First evaluation, done in two-dimensional PC software, have shown results that consent with the newest standards for designing critical details in passive houses.

Second, environmental evaluation of building envelope constructions (EE – embodied energy, $CO^2$ emissions, $SO^2$ emissions) using EPS thermal insulation with graphite addition, showed lower emission compared to other materials used commonly in passive house design.


## Acknowledgments

This study was financially supported by Grant Agency of Slovak Republic to support of projects No. 1/0307/16.


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