

Design of a Residential Building as a Low Energy House in order to Improve Building Energy Efficiency

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ABSTRACT: Efficient use of energy is important since the global energy resources are finite and power generation using fossil fuels has adverse environmental effects. As buildings are the biggest users of energy in Europe, representing approximately 40% of energy consumption in the European Union (EU), it is vital that we make our buildings more energy efficient. The measures are being applied across all EU countries and are in line with the European Directive for the Energy Performance of Buildings (EPBD). The paper investigates whether different design approaches were considered when designing energy efficient buildings and what criteria for design were used in accordance with architectural research to constructing low energy buildings. It also examines if there were any implications to constructing such low energy building designs compared to the traditional designs besides cost budget and resource use. In the paper, this is demonstrated with a case study of a residential building where the building is constructed as a low energy house and various thermal assessments were carried out in relation to its design and energy balance in order to improve building energy efficiency. Furthermore, a comparison study was prepared between this selected passive house with improved standards and the same house design with common standards in order to justify the energy efficiency levels achieved, which is also presented on a graphical scale known as energy labelling of buildings as part of EPBD implementation throughout the EU countries.

Keywords: building energy efficiency, low energy house, energy labelling, thermal evaluation, solar energy

1. BACKGROUND

Energy efficient building design is usually location dependent and therefore the local climate must be considered when selecting appropriate design strategies in order to optimise the designs for energy use and other resources such as the use of passive solar techniques. Generally the energy saving policy influences the architectural design of a building and newly

designed buildings should comply with the requirements for low energy consumption and for utilisation of alternative energy sources [1].

In addition, efficient use of energy is important as the global energy resources are finite and power generation using fossil fuels has adverse environmental effects. In Europe buildings are the biggest users of energy representing approximately 40% of energy consumption in the European Union

(EU) and therefore it is crucial to improve buildings' energy efficiency and apply necessary measures across all EU countries, which are in line with the European Directive for the Energy Performance of Buildings (EPBD) [2].

2. BUILDING DESIGN

2.1 Design of a residential building as a low energy house

Energy saving policy influences the architectural design of a building and newly designed buildings should comply with the requirements for low energy consumption and for utilisation of alternative energy sources mainly solar radiation.

The case study building is a residential building and it is constructed as low energy house (see figure 1).

2.2 Design concept

The designed building consists of two floors and one basement. The main design characteristics of the building are:

- Built up volume: 1796 m³
- Built up area: 235 m²
- Building floor dimensions: 11.6m x 20.6m

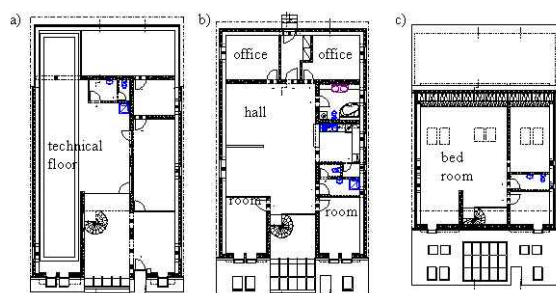


Figure 1: Scheme of the section and floor plans of the designed building

The load bearing vertical structure is designed from masonry system of lightweight concrete blocks of thickness 300 mm. The monolithic concrete floor structure and a ventilated pitched roof were designed. Southern facade is fully glazed and constructed in a slope of 60°. Northern facade is highly insulated. Thermal

insulation of mineral wool was used for the roof and the building facade. Basement is under the ground on the north part of the building. Windows with triple glazed units in wooden frames were selected. The u-values for each building component are in the following [W.m⁻²K⁻¹]:

- The whole window: $U_w = 0.84 \text{ W.m}^{-2}\text{K}^{-1}$
- The glazing: $U_g = 0.5 \text{ W.m}^{-2}\text{K}^{-1}$
- The frame: $U_f = 1.14 \text{ W.m}^{-2}\text{K}^{-1}$
- Wooden door – $U_d = 1.0 \text{ W.m}^{-2}\text{K}^{-1}$
- Glazed facade - $U_f = 0.75 \text{ W.m}^{-2}\text{K}^{-1}$
- Peripheral wall - $U_p = 0.12 \text{ W.m}^{-2}\text{K}^{-1}$
- Pitched roof - $U_r = 0.11 \text{ W.m}^{-2}\text{K}^{-1}$
- Ground floor - $U_g = 0.12 \text{ W.m}^{-2}\text{K}^{-1}$

2.3 Thermal evaluation

Thermal assessment of the building design and energy balance were completed. The following tables are showing annual energy balance as well as energy label of the building (see tables I and II):

Table I: Annual energy balance of the building

Heat demand for heating according to EN 832 and CSN EN ISO 13790	
Demand for heating due to heat losses:	18.353 MWh
Internal heat gains:	4.454 MWh
Solar heat gains:	6.211 MWh
Total heating energy demand for heating:	9.028 MWh
Heat consumption 10.2 kWh.m ² per year => Passive Building Standard	

Table II: Energy label of the building

Average heat transfer coefficient	
$U_{\text{average calculated}} = 0.18 \text{ W.m}^{-2}\text{K}^{-1}$	
Required average heat transfer coefficient (according to the requirements of CSN 73 0540)	
$U_{\text{standard requirement}} = 0.59 \text{ W.m}^{-2}\text{K}^{-1}$	
Energy label STN = $U_{\text{average calculated}} / U_{\text{standard requirement}} \times 100 = 31 \%$ - High Energy Efficiency	

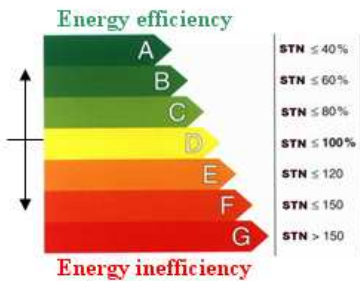


Figure 2: Energy label (STN) of the building in accordance of CSN 730540:2007 [3] (Czech design standard for thermal protection of buildings)

Moreover, the computer simulation program AREA 2005 [4] was used for evaluation of characteristic details (see figures 3 to 6).

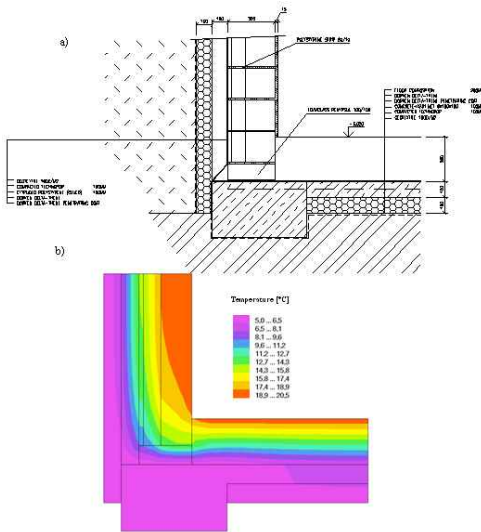


Figure 3: Detail of thermal insulation peripheral wall in the contact with foundations: a) description of the detail, b) 2-D thermal evaluation of temperature distribution

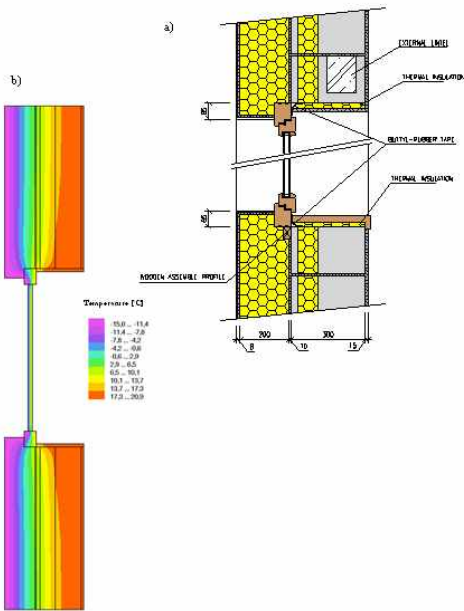


Figure 4: Detail of the peripheral wall with a window: a) description of the detail, b) 2-D thermal evaluation of temperature distribution

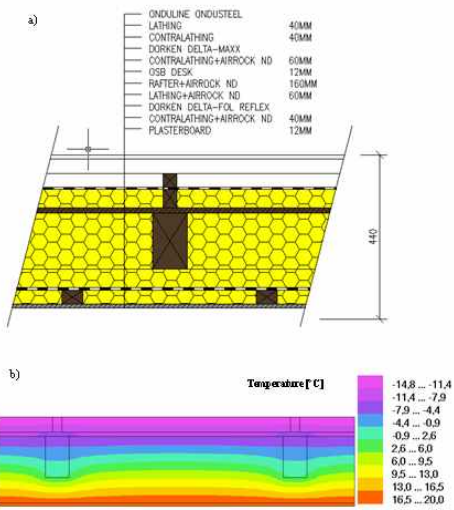


Figure 5: Detail of the pitched roof composition: a) description of the detail, b) 2-D thermal evaluation of temperature distribution

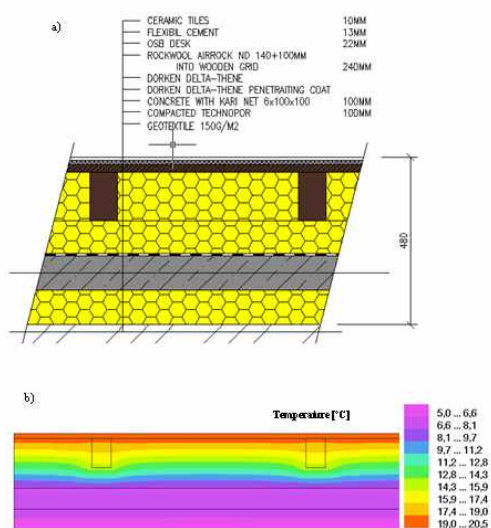


Figure 6: Detail of the floor composition – floor finishing and waterproofing on ground: a) description of the detail, b) 2-D thermal evaluation of temperature distribution

3. BUILDING ANALYSIS

The paper aimed at investigating the approaches taken towards designing energy efficient buildings and the criteria used for design in accordance with architectural research to constructing low energy buildings. In order for the investigation, the following questions were asked:

Q1: Was the architect considered a different design approach for this design specifically or was it only improving the building fabric?

The building was designed in accordance with the architectural research to achieving a low energy building and the main architectural idea behind the building design is to maximise solar gains and minimise heat losses. As a result, the building is constructed with fully glazed sloped southern facade. The northern part of the building has minimal glazing as well as is highly insulated and partly hidden under ground.

Q2: What were the implications to designing such a low energy design compare to other normal house designs besides cost and resource use?

The main implication was to implement very low U-values and to design as a passive house standard with very low heat losses through the building envelope.

Below are the tables showing construction U-values compared against other building standards as well as a comparison of energy data analysis [5] (see tables III and IV):

Table III: U-values

Const.	U-values [W/(m ² K)]			
	Passive House	Wooden Variant	Com. House	Req. Stds.
Wall	0.12	0.13	0.28	0.30
Floor	0.12	0.12	0.39	0.6
Roof	0.11	0.11	0.21	0.24
Window	0.84	0.84	1.6	1.7

Table IV: Energy data

	Passive House	Wooden Variant	Common House
Energy demand for heating [GJ]	30.264	36.300	205.252
Energy demand for heating [kWh]	8407	10083	57014
Area of building surface [m ²]	882.1	882.1	882.1
Energy demand per m ² of surface [kWh/m ² .a]	9.53	11.43	64.63
Average U-value of surface of the building [W/(m ² K)]	0.17	0.20	0.38

4. CONCLUSION

The study in this paper have demonstrated that achieving building energy efficiency is not only possible but also feasible by taking a strategic design approach at the early design stages and

working the building detail towards completion with sensible consideration.

Furthermore, this is a reminder for all architects, engineers, project managers and other professionals involved in the building design process to understand the importance of energy efficiency and the steps to designing such highly efficient buildings.

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