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Peter Turcsanyi, Anna Sedlakova
Technical University of Kosice, Civil Engineering Faculty,
Institute of Architectural Engineering

THERMO-PHYSICAL EVALUATION OF AN ULTRA-LOW-ENERGY FAMILY HOUSE

Термін "енергоощадний будинок" дуже добре відомий інженерам і архітекторам у всьому світі. У часи мінімізації енергетичних навантажень і негативних викидів енергоефективний будинок є одним з кращих способів ознайомитися з європейськими потребами "20-20-20". Описано методи спорудження зовнішніх огороджень однородинного енергоощадного будинку, розташованого у Словацькій Республіці. Однородинний будинок розроблено із врахуванням архітектурних, екологічних і конструктивних вимог чинних європейських директив, спрямованих на енергетичну ефективність та ефективність використання енергії. Енергоощадність будинку оцінювали за допомогою одновимірного теплофізичного програмного забезпечення TEPLO. Пасивний будинок не є енергетичним стандартом, а є інтегрованою концепцією забезпечення високого рівня комфорту, який можна використати і для енергоощадних будівель. Концепція пасивного будинку не містить будь-яких числових значень і придатна для всіх кліматичних умов. Ультранизькоенергетичні будівлі не було "винайдено" будь-ким: насправді цей принцип було розроблено. Теплового комфорту досягають завдяки пасивним заходам (ізоляція, рекуперація тепла, пасивне використання сонячної енергії та внутрішніх джерел тепла). Наведено числові та графічні результати дослідження проекту. Мета досліджень полягала у визначенні енергетичного та екологічного впливу спроектованої будівлі на довкілля, зокрема для можливості прогнозування та мінімізації екологічного навантаження на природу і суспільство в разі реалізації енергоощадного будинку.

Ключові слова: ультра-низькоенергетичний однородинний будинок, ефективність використання енергії, огородження будівлі.

Ultra-low-energy 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, energy efficient houses are one of the best ways to meet European "20-20-20" targets. The main topic of this paper is to create a building envelope assessment of an ultra-low-energy family house designed for Slovak Republic climate. Family house was designed taking in account architectural, environmental and constructional requirements of today´s European directives focusing on energy performance and energy efficiency. Ultra-low-energy house was evaluated in one dimensional thermo-physical software TEPLO. The Passive House is not an energy standard but an integrated concept assuring the highest level of comfort. The integrated concept doesn't contain any numerical values and is valid for all climates. This definition shows that the Passive House is a fundamental concept and not a random standard. Ultra-low-energy building have not been "invented" by anyone – in fact, this principle was discovered. Thermal comfort is achieved to a maximum extent through passive measures (insulation, heat recovery, passive use of solar energy and internal heat sources). Results of this project are displayed in numbers as well as in graphic figures. Our goal was to find out how the designed building will perform energetically and environmentally so we could predict and minimize environmental load on nature and society in case of its actual realization.

Key words: ultra-low-energy family house, energy efficiency, building envelope.

Introduction. 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. 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 years 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 %. Word "energy" gained a strong meaning over the last few years. Energy is among the principal factors of the social and economic development of our society, dealing with important issues, such as politics and the environment [1]. An increasing interest in many aspects related to buildings energy efficiency has led to a growing amount of research and studies. Some of these aim at investigating the economic and financial feasibility of energy efficiency measures currently applied in the building sector, as well as deepening to what extent the energy performance of buildings could be able to affect the market price or the rent of real estate units [2]. One of the basic way of saving heat loses is sufficient building envelope insulation, however, efficiency of thermal insulation has its limits. One study [3] deals with the optimum thickness of adding insulation. Results indicate that adding insulation is not always beneficial, and thus in particular in the regions of Mediterranean climate as susceptible to anti-insulation behavior [3].

Ultra-low-energy family house envelope specification

Fig. 1. Real view at ultra-low family house

House that is being evaluated is located in Košice, Slovak Republic. City of Košice lies at an altitude of 206 meters above sea level and covers an area of 242.77 square kilometers. It is located in eastern Slovakia, about 20 kilometers from the Hungarian borders, 80 kilometers from the Ukrainian borders, and 90 kilometers from the Polish borders (Fig. 2). It is about 400 kilometers east of Slovakia's capital Bratislava. Košice city is situated on the Hornád River in the Košice Basin, at the easternmost reaches of the Slovak Ore Mountains. More precisely it is a subdivision of the Čierna hora Mountains in the northwest and Volovské vrchy Mountains in the southwest. The basin is met on the east by the Slanské vrchy Mountains [4]

Fig. 2. Locality of the ultra-low-energy family house

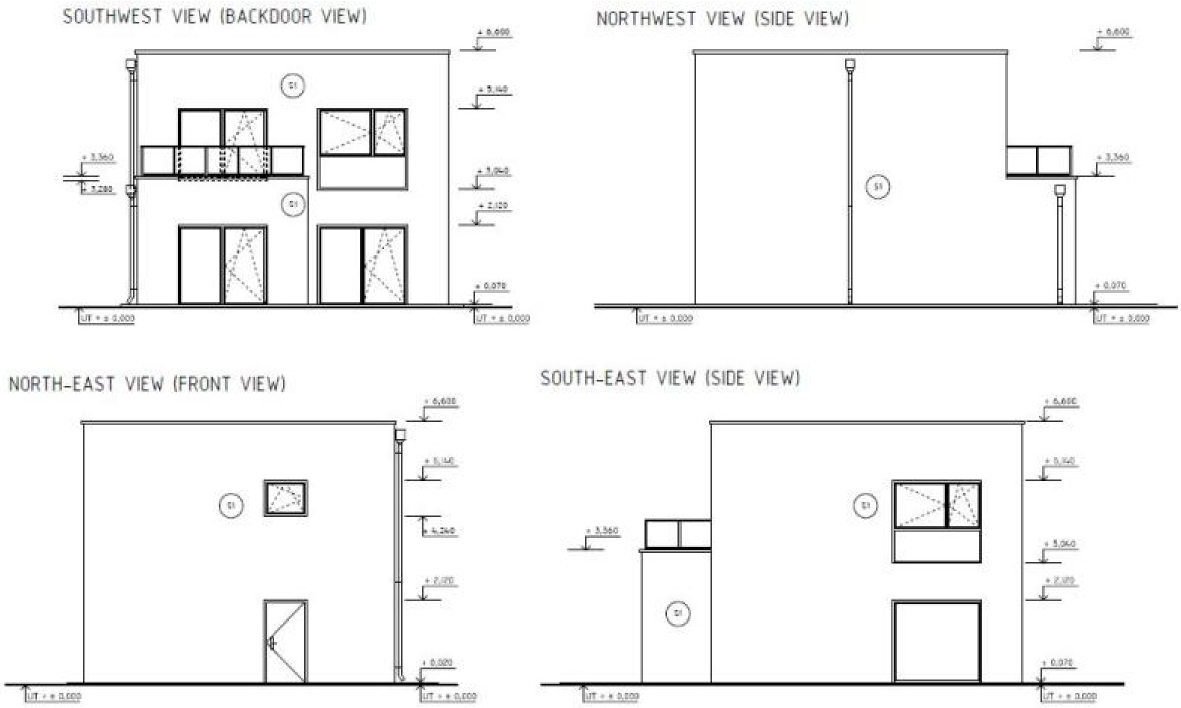

Fig. 3. Project views of the ultra-low-family house

Evaluated ultra-low-energy house has its building envelope constructed using ECOB panels with flat roof system. In cross-section the panels are "puzzle-like" to achieve better connection between individual panels. Fig. 3 shows schematic illustration of external wall composition and scheme of cut A and B.

Table 1

Building envelope wall composition – cut A

	d [m]	λ [W/m.K]	c [J/kg.K]	ρ [kg/m^3]	m [kg/m^2]
Gypsum plaster	0.005	0.570	1000.0	1300.0	10.0
RFC	0.070	1.580	1020.0	2400.0	29.0
Neopor insulation	0.330	0.031	1250.0	18.0	45.0
Adhesive mortar	0.005	0.800	920.0	1300.0	18.0
Silicon render	0.003	0.700	920.0	1700.0	37.0

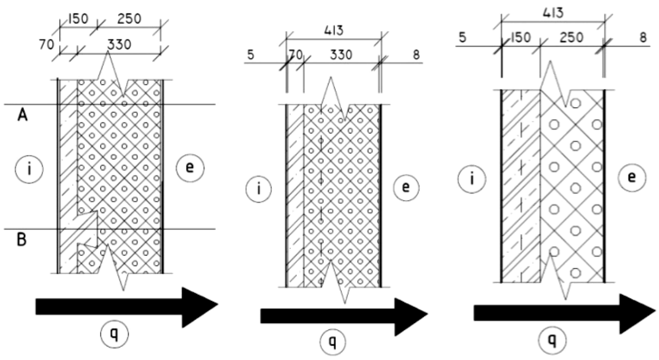

Fig. 4. Wall layout view and schemes of cut A and B of external wall

Table 2

Building envelope wall composition – cut B

	d [m]	λ [W/m.K]	c [J/kg.K]	ρ [kg/m^3]	m [kg/m^2]
Gypsum plaster	0.005	0.570	1000.0	1300.0	10.0
RFC	0.150	1.580	1020.0	2400.0	29.0
Neopor insulation	0.250	0.031	1250.0	18.0	45.0
Adhesive mortar	0.005	0.800	920.0	1300.0	18.0
Silicon render	0.003	0.700	920.0	1700.0	37.0

Tables I and II describe thermo-physical parameters for external wall compositions:
d thickness [m]; λ thermal conductivity coefficient [W/(m.K)]
c specific heat capacity [J/(kg.K)]; ρ density [kg/m^3]; m area weight [kg/m^2]

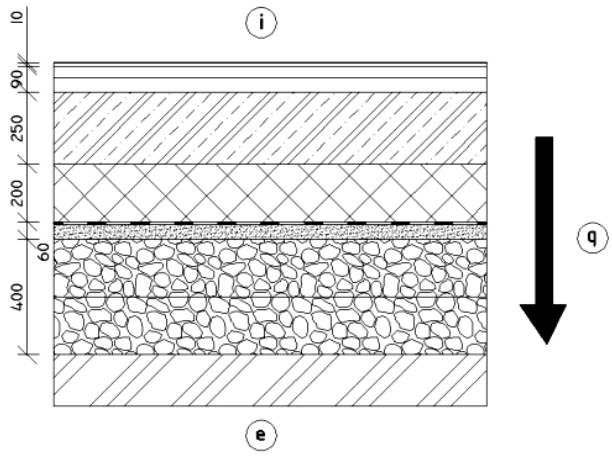

Fig. 5. Floor on the ground

Table 3

Thermo-physical parameters for material composition of floor on the ground

	d [m]	λ [W/m.K]	c [J/kg.K]	ρ [kg/m^3]	m [kg/m^2]
Ceramic tiles	0.010	1.010	840.0	2000.0	200.0
Concrete	0.090	1.300	1020.0	2200.0	20.0
RFC slab	0.250	1.580	1020.0	2400.0	27.0
EPS NEO	0.200	0.031	1250.0	18.0	45.0
Stud membrane	0.0005	0.140	1100.0	1200.0	50000
Sand layer	0.050	0.950	960.0	1750.0	4
Gravel	0.400	0.650	800.0	1650.0	15

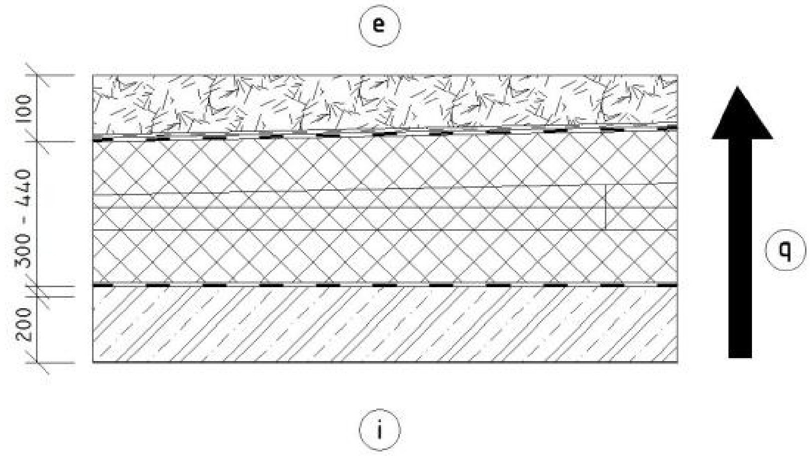

Fig. 6. Roof composition

Table 4

Thermo-physical parameters for material composition of roof

	d [m]	λ [W/m.K]	c [J/kg.K]	ρ [kg/m^3]	m [kg/m^2]
Gypsum plaster	0.005	0.570	1000	1300	10.0
RFC	0.200	1.580	1020	2400	29.0
Vapor barrier	0.004	0.170	1470	1300	375000
EPS Stabil150	0.300	0.039	1250	19.0	40.0
Water- proofing	0.0015	0.350	1470	1313	24000
Gravel	0.100	0.650	800	1650	15.0

Openings and HVAC systems. All family house openings such as windows, entrance door and doors to backyard at ground floor with “balcony door” at the first floor, were designed according to STN EN 73 0540 – 2:2012. Windows are used as triple-glazed window with 7-chambers frame SCHÜCO ALU INSIDE. Entrance door is used as SCHÜCO ADS 112.IC.

HVAC systems. All HVAC systems are being secured by one compact unit NILAN Compact K. Heating is provided by floor heating system. First floor is being heated by ceiling infrared panels. These panels are made from matt white carbon fiber with an aluminum frame, the simple design blends well on most ceilings or can also be fitted high on the wall like a picture. Panels have a long 3 meters flex which we recommend is wired to a programmer or thermostat by an electrician [5]. Ground and first floor are being air-cooled by ventilation system connected to heat recovery unit of energy source NILAN Compact K. Heat pump based on air-water principle, part of NILAN Compact K. Forced ventilation in installed to the whole house securing optimum and healthy indoor environment connected on heat recovery unit.

Methods of determination of energy aspects. Thermo-physical parameters were calculated according to STN EN 730540: 2012 for following climatic conditions [25]:

- outdoor air temperature θe = -13 °C;
- indoor air temperature θi = 21 °C;
- relative humidity outdoors Rhe = 84 %;
- relative humidity indoors Rhi = 55 %.

For determination of heat transfer coefficient and temperature distribution were used software AREA 2010 and TEPLO 2010 from the Svoboda Software package.

Results. In Table 5 are presented values of heat transfer coefficient U for all constructions of building envelope and compared with recommended values for ultra-low energy buildings according to STN EN 730540: 2012.

Table 5

Thermo-physical results (U, R)

	Calculated U [W/m^2.K]	Recommended U [W/m^2.K] valid	
		31.12.2020	01.01.2021
External wall - cut A	0.089	0.22	0.15
External wall - cut B	0.12	0.22	0.15
Roof	0.123	0.10	0.10
Window	0.66	1.00	0.60
Door	0.1	0.1	
	Calculated R [m^2.K/W]	Recommended R [m^2.K/W]	
Floor on the ground	7.98	2.50	2.50

Fig. 6 illustrates temperature distribution in constructions of building envelope wall type A and type B.

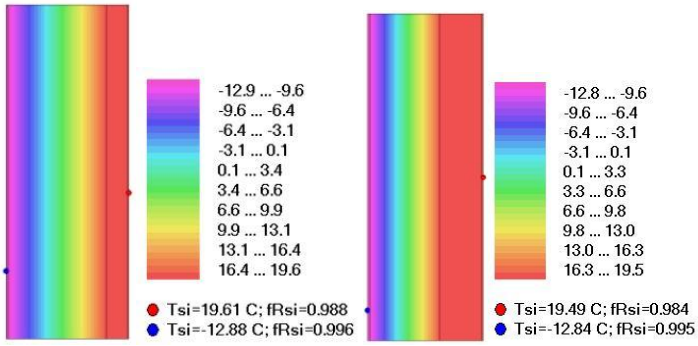

Fig. 7. Cut A and cut B temperature distributions using 1-D software TEPLO

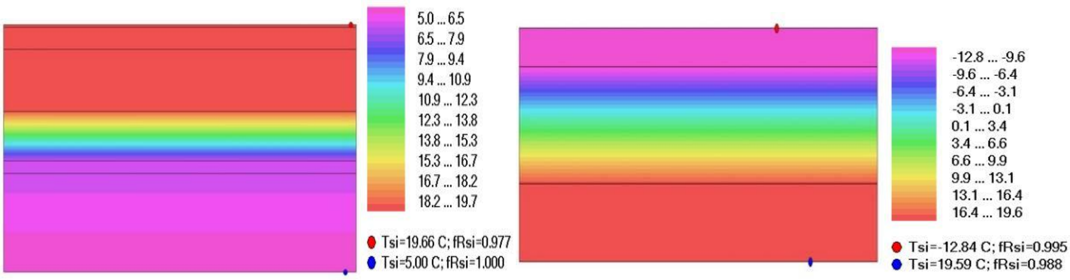

Fig. 8. Floor on terrain and roof temperature distribution using 1-D software TEPLO

Conclusion. Outer local climate and indoor conditions were used in this analysis according to European and National directives. Family house, designed and constructed in Košice, Slovakia was studied from energy performance point of view. The objective of this case study was to analyze whether the criteria for ultra-low-energy class were fulfilled from the building envelope thermo-physical side. According to PHPP software the primary energy demand in evaluated family house achieved value of 53 kWh/m^2.a. Thus this house fulfills "A0" category and can be considered as ultra-low-energy house.

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