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Effect of two different types of building envelope insulation on future heating demand of a family house using simulation software

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Abstract. Computer programs allowing determining accuracy of building design in advance, or its parts, from the thermal engineering point of view are on the rise. Finding the most suitable project design for optimizing future energy performance of building significantly contributes to implementation of European Directive on Energy performance of buildings 2010/31/EU in Slovakia. Using simulation software, DesignBulder in this case, became a very useful tool on the road to energy effective design. In this paper, we have placed a virtual family house (which will be built in Kosice, Slovakia) to the simulation software DesignBuilder and were finding out the most suitable design in case of future heating demand. Family house was designed taking in account architectural, environmental and constructional requirements of today´s directives focusing on energy performance and energy efficiency. Results of this project are displayed in numbers as well as in graphic figures. Our goal was to find out the difference between two different types of envelope wall insulation.

1. Introduction

The result of architectural and construction solution affect many parameters. Those parameters either can or cannot be affected by designer; nevertheless, first raw design usually needs to be optimized according to importance of energy efficiency of building. Finding optimal solution means knowing correlation between key parameters which are affecting energy performance of buildings (i.e. heat demand, cooling demand, thermal comfort, etc.). After simulation on energy performance of building, designers are able to optimize parameters to find the best ratio between initial cost and long term energy save. Currently, there are more than 400 applications that can be applied to analyzing building energy and thermal simulation [1].

Building thermal simulation tools predict the thermal performance of a given building and the thermal comfort of its occupants. In general, they support the understanding of how a given building operates according to certain criteria and enable comparisons of different design alternatives [2]. Evaluation of thermal comfort involves assessment of at least six factors: human activity levels, thermal resistance of clothing, air temperature, mean radiant temperature, air velocity and vapour pressure in ambient air [3]. In this paper, we are comparing two different types of external wall insulation and their effect on heat demand for heating. First is commonly used wall thermal insulating material EPS polystyrene, part of ETICS system. On the other hand, as the age and research go further every day and new materials are being introduced into everyday construction life, insulation based on phenol insulation board is being assessed in this paper.

2. Theory

House that is being evaluated is located in Košice-Krasna, 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 (figure 1). 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]

Figure 1. Position of Kosice city and detailed location of evaluated family house

Two-storey family house represents a typical type of residential buildings built in this area. The floor layouts were designed for a family of two parents and three kids and the concept of a whole house was made in according to the latest energy standards. Building is based on a concrete footing foundation. The family house envelope was designed using materials with high thermal capacity. As for thermal insulation - thick layer of polystyrene (ETICS system)is being used, to minimize the heat loses during the heating period as well as to prevent the heat transfer during the summer period. Roof structure creates unconditioned spade between insulated ceiling and top of the roof. Transparent parts of building envelope were designed as wood-aluminum, triple glazed windows Internorm with outside louvers for a regulation of solar gains through the windows.

2.1. Phenolic insulation

The main use of phenolic foam in construction is as thermal insulation, to improve is thermal efficiency. The thermal efficiency of the existing building stock is of prime concern, if carbon emissions targets are to be met. For those homes with solid walls, external wall insulation can be an effective method of improving their thermal efficiency. Phenolic foam is starting to be popular material choice for external wall insulation systems owing to its low thermal conductivity and good fire performance [5]. Phenolic foam is made from three main components: phenolic resin, a blowing agent and an acid catalyst; a number of additives can also be utilised to develop specific properties within the foam. There are patents and other information available at [6] that describe the chemicals used to manufacture phenolic foam.

3. Materials and methods

The external wall insulated with polystyrene represents the most common insulation type of ETICS insulating system. On contrary, phenolic insulation materials are used quite rarely – but they are on the rise. The main reason is its price, which is extensively higher than polystyrene (or any other classical insulation material). However, phenolic insulation boards allow us to design energy efficient building while keeping the external wall construction as subtle as possible due to its low coefficient of thermal conductivity of λ=0,020 W/m·K. With its thickness, phenolic insulation board of thickness 6 cm equals to 12 cm of polystyrene.

Table 1 Physical and thermal parameters of building

Shape factor (A/V ratio)	0.78 1/m
Volume of building space	726.18 m^3
Total heat transfer surface	569.48 m^2
Total floor area	222.09 m^2
Wall U-Value	0.148 $W/(m^2\cdot K)$
Insulated ceiling U-Value	0.123 $W/(m^2\cdot K)$
Ground floor R-Value	4.38 $(m^2\cdot K)/W$
Wood-aluminum U-Value Internorm HF 350	0.60 – 0.95$W/(m^2\cdot K)$

3.1. Technical parameters of an envelope wall type A – polystyrene insulation

Envelope wall type A is a classic type of the external envelope wall insulated with EPS polystyrene. Polystyrene insulation is the most common insulating material used in Slovak Republic. Polystyrene insulation is being put on masonry or any other wall structure, using adhesive mortar and anchors.

Table 2. Thermo-physical properties of an envelope wall type A

	d [m]	λ [W/m·K]	c [J/kg·K]	ρ [kg/m^3]	m [kg/m^2]
Plaster	0.020	0.570	1000.0	1300.0	10.0
Porotherm 38 Ti Profi	0.380	0.134	1000.0	750.0	29.0
EPS insulation	0.120	0.038	1050.0	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

3.2. Technical parameters of an envelope wall type B – phenolic insulation

Envelope wall type B is a type of the external envelope wall insulated with phenolic boards, in this case Kingspan KOOLTHERM K5. The core of Kingspan Kooltherm K5 External Wall Board is a fibre–free performance rigid thermoset phenolic insulant manufactured with a blowing agent that has zero Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP). The core of Kingspan Kooltherm K5 External Wall Board has a 90% closed cell structure. Phenolic board insulation is being put on masonry or any other wall structure, using adhesive mortar and anchors.

Table 3 Thermo-physical properties of an envelope wall type B

	d [m]	λ [W/m·K]	c [J/kg·K]	ρ [kg/m^3]	m [kg/m^2]
Plaster	0.020	0.570	1000.0	1300.0	10.0
Porotherm 38 Ti Profi	0.380	0.134	1000.0	750.0	29.0
Phenolic insulation	0.060	0.020	800.0	35.0	300.0
Adhesive mortar	0.005	0.800	920.0	1300.0	18.0
Silicon render	0.003	0.700	920.0	1700.0	37.0

4. Simulation

Using simulation software DesignBuilder, the assessed family house was simulated. In the first simulation, polystyrene was used as wall insulation. Second simulation shows the alternative to EPS insulation - phenolic insulation board.

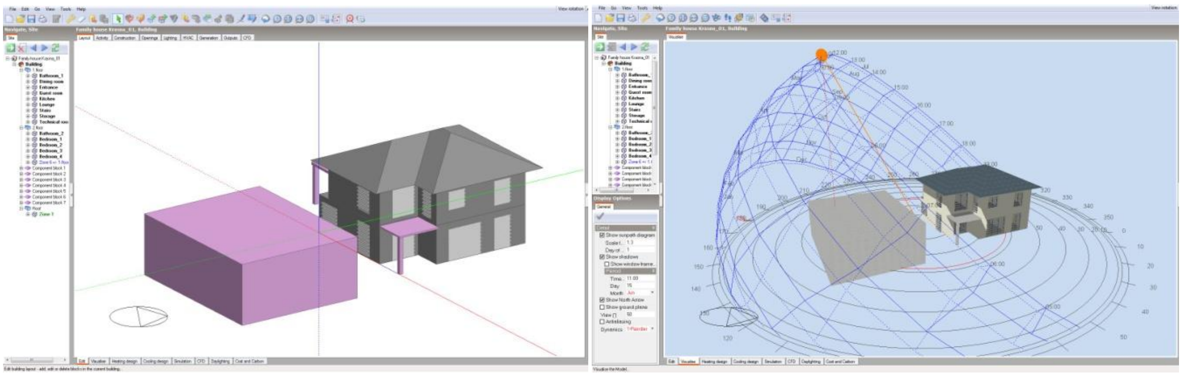

Figure 2. Family house created in DesignBuilder interface and its visualization

Weather data of the reference year for Kosice were used in this simulation. They provide inputs of dry bulb air temperature, relative humidity, solar radiation, wind speed, wind direction etc., for achieving the most accurate and realistic simulation.

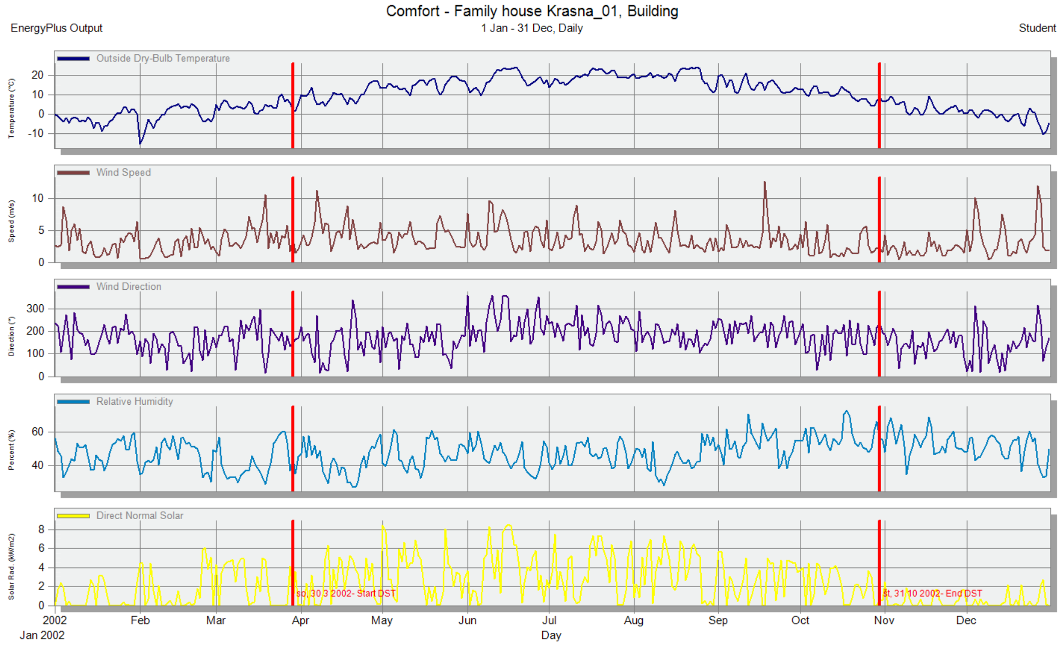

Figure 3. Weather data for the reference year in Košice, Slovakia. From the top: Outside dry-bulb temperature, wind speed, wind direction, relative humidity, solar intensity

5. Results

Building simulations were set up with the DesignBuilder v4 software, in which building performance data were generated by the simulation engine EnergyPlus.

5.1. Envelope wall type A – polystyrene insulation

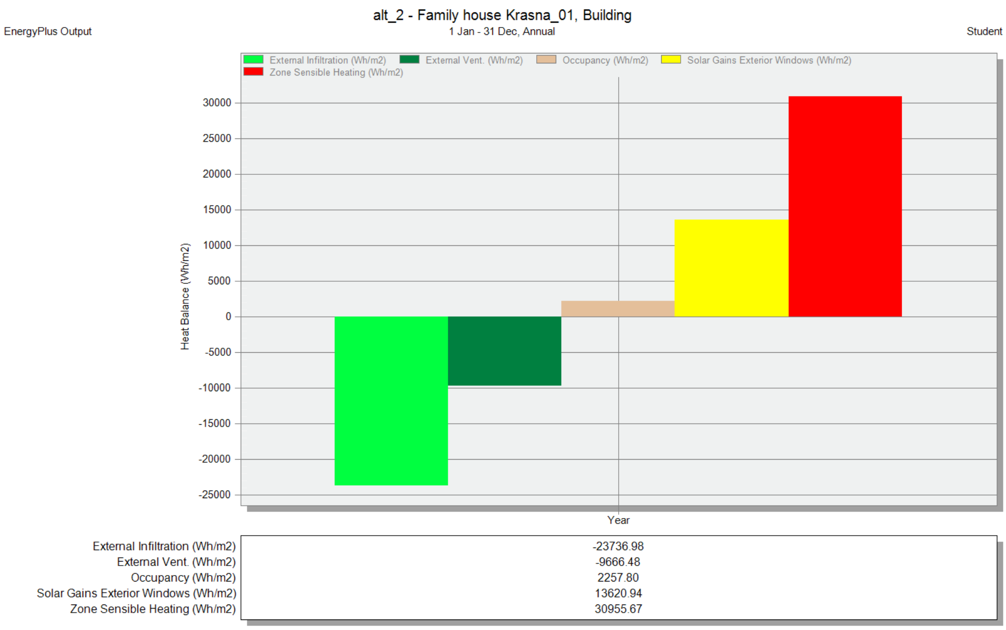

Figure 4. EnergyPlus outputs of annual heat gains, heat losses and heating demand of type A

Figure 4 shows annual heating demand of a family house, with envelope wall insulated by EPS polystyrene alternative, on square meter of floor area is 30,96 $kWh/m^2 \cdot a$. Solar gains through the exterior windows are 13,62 $kWh/m^2 \cdot a$ and a heat gains from the occupancy 2,2 $kWh/m^2 \cdot a$. On the other hand heat losses via external infiltration and ventilation are little higher than 32 $kWh/m^2 \cdot a$.

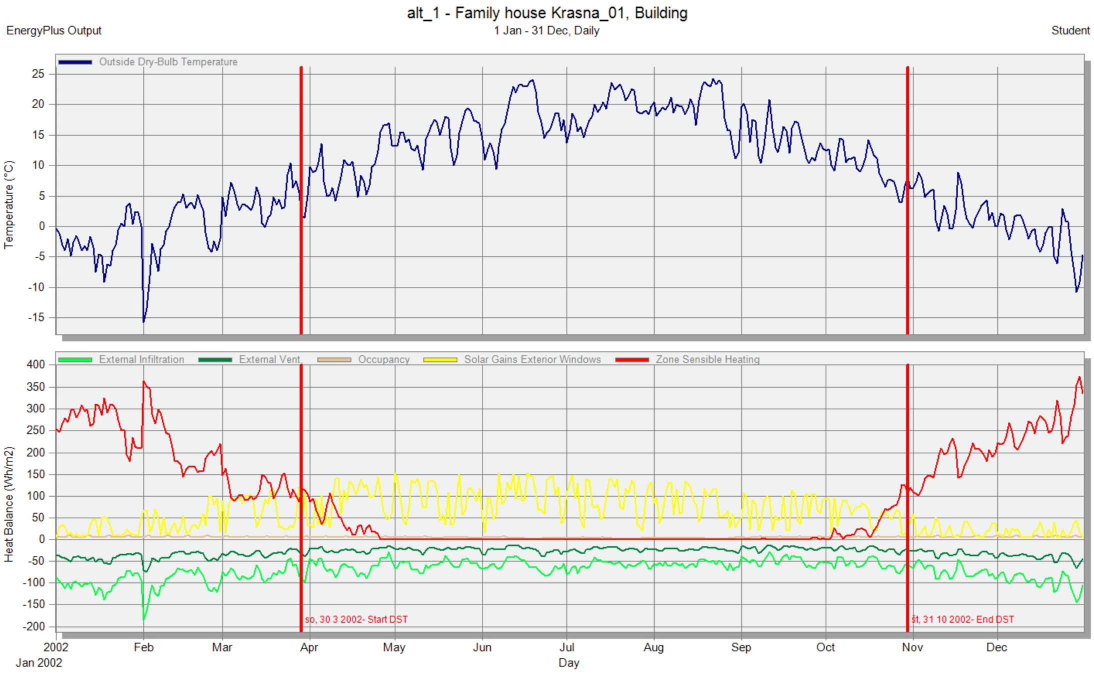

Figure 5. Daily data of heating demand, solar gains through exterior windows, heat gains from occupancy, losses from infiltration and ventilation

As seen on figure 5, daily extremes on heating demand peak on 1st of February, with over 0,35 kWh/m^2. This, of course is a result of the outside dry-bulb temperature drop.

5.2. Envelope wall type B – phenolic insulation

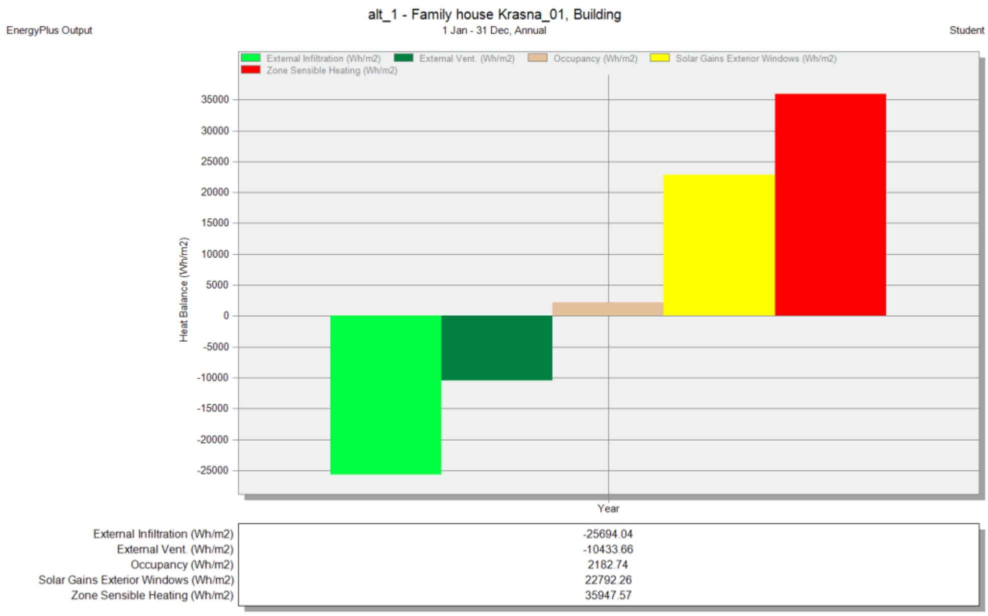

Figure 6. EnergyPlus outputs of annual heat gains, heat losses and heating demand of type B

Figure 6 shows annual heating demand of a family house, with envelope wall insulated by phenolic insulation board alternative, on square meter of floor area is 35,9 kWh/m^2·a. Solar gains through the exterior windows are 13,62 kWh/m^2.a and a heat gains from the occupancy 2,2 kWh/m^2·a. On the other hand heat losses via external infiltration and ventilation are little higher than 32 kWh/m^2·a.

6. Conclusion

Nowadays, not only in Slovakia but worldwide, building sector is heading towards emissions-free goal. Every day, more and more new and efficient materials are being implemented into construction process. One of these materials with future is phenolic insulation. Classical insulation used in ETICS systems such as polystyrene, mineral wool, etc., with thickness over 20cm, are being slowly replaced by thinner and subtle insulation materials – such as phenolic boards. As seen from results, envelope wall insulated by polystyrene with thickness of 12cm, can be replaced by phenolic insulation board with the thickness equal to half of polystyrene – 6cm. Heating demand is affected by 5 kWh/m^2 annually. Given the price for 1 kWh, total amount of finances saving equals to 35 € a year, which is not considered as a significant improvement in saving costs on heating. One of the biggest cons of phenolic insulations is its high price. Compared to polystyrene insulation material used in this paper, it doubles the price with over 17 €/m^2.

With more energy efficient materials with very low coefficient of thermal conductivity, such as phenol based insulation systems, it is possible reaching goals as net-zero energy buildings or even energy plus buildings while making building envelope structure more subtle and modern. With the help of simulation tools, such as DesignBuilder, it is feasible to find the most efficient option for building structures, taking into account costs on future energy demand as well as costs on construction itself.

Acknowledgments
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References

[1] Energy Efficiency and Renewable Energy (EERE). Building Energy Software Tools Directory, U.S. Department of Energy. Available online: http://apps1.eere.energy.gov/buildings/tools_directory/(accessed on 18 January 2013).
[2] Maile, T.; Fischer, M.; Bazjanac, V. *Building Energy Performance Simulation Tools—A Life-Cycle and Interoperable Perspective*; Stanford University: Stanford, CA, USA, 2007.
[3] Fanger, P.O. *Thermal Comfort, Analysis and Applications in Environmental Engineering*; McGraw-Hill Book Company: New York, USA, 1970.
[4] *Available: https://en.wikipedia.org/wiki/Ko%C5%A1ice.*
[5] Densley Tingley, Hathway, Davison, Allwood. *The environmental impact of phenolic foam insulation boards,* Proceedings of the Institution of Civil Engineers, Volume 170 Issue 2, April, 2017, pp. 91-103, 2015.
[6] Kingspan Holdings Limited (2006) A Phenolic Foam. International Patent Application No. PCT/IE2006/000096, 8 September.