Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

COMPARISON STUDY BETWEEN A PITCHED ROOF AND A FLAT ROOF FOR A 2-STOREY HOUSE

Alexandru Florin PITROACA, Simon Alexandru PESCARI, Valeriu-Augustin STOIAN, Clara-Beatrice VÎLCEANU

Politehnica University Timisoara, 2 Piata Victoriei Street, Timisoara, Romania

Corresponding author email: alexandru.pitroaca@upt.ro

Abstract

The purpose of this study is to see the differences between the investment costs and the energy efficiency for two types of roofs for a 2-storey house located in Timisoara, Romania. The paper contains a comparison of the costs and energy demand between a pitched roof and a flat roof. The energy demand will be calculated using the stationary method with a modeling program. The study focuses only on the effects of choosing between the two types of buildings roofs, so the dimensions of buildings, characteristics of the buildings envelope (exterior walls, windows and doors, ground floor slab) and the installation systems remain the same.

Key words: *energy efficiency, pitched, flat, roof.*

INTRODUCTION

The building sector energy consumption is in a continuous increase (Loukaidou et al., 2017). Buildings are responsible for about 40% of global energy use and for 36% of greenhouse gas emissions in the EU and from the total amount of energy involved in buildings, a total of 60% is used for heating and cooling them (Qiong et al., 2019; Maduta et al., 2022; Pescari et al., 2022).
In this context, there is a need to decrease the energy consumption of buildings, according to actual Regulations (Zhang et al., 2022).
One of the main elements of a building in terms of energy consumption, is the building envelope (Zhang et al., 2022). The building envelope is defined as the totality of the surfaces of the perimeter construction elements, which delimit the interior (heated) volume of a building, from the outside environment or unheated spaces outside the building.
Considering the roles of envelope, the proper design and selection of materials are an efficient way to reduce the thermal transfer between a building and the environment (Kaynakli, 2012; Stachera et al., 2022).
The buildings roofs are an important element of envelope in energy efficiency because thru them a significant amount of heat is lost and a significant amount of solar radiation is absorbed (Abuseif, 2018).
In this context, the paper presents a study between two types of roofs for a two-storey house located in Timișoara, Romania. The purpose of this paper is to highlight if there is an important difference in terms of energy reduction between two types of buildings roofs.

MATERIALS AND METHODS

It is proposed to conduct a case study on a residential building. The analysed building is a single-family house with two apartments, located in the municipality of Timișoara, having a height regime of Gf+1F (Figures 1 and 2). It was started to be built in august 2022, the resistance structure being made of masonry walls. The building is moderately sheltered and has more than one exposed façade.
The study involves the calculation of the energy required for heating the house using, in turn, the two types of roofs. The calculation of the energy required for heating was performed using the monthly calculation method with steady state.
The steady state is a conventional thermotechnical calculation hypothesis, within which assume that temperatures do not vary with time. The building was examined in climate zone II using a steady state simulation software.

The study also presents the differences between the investment costs of the house with both type of roofs. The construction costs of the house are real, not estimated, because the house is already in construction and the roof is realised in the "flat roof" manner.
The study focuses only on the effects of choosing between the two types of roofs, so the dimensions of buildings, characteristics of the buildings envelope and the installation systems remain the same. The envelope elements were designed so that the thermal transmittance fulfils the minimum requirements of the Romanian Regulations (Charisi, 2017).
As already stated, the analysed building is a two-storey residential house with the resistance structure made of masonry walls. Heating is realized by means of two local thermal plants that use natural gas as fuel.
The ground floor is almost identical for both apartments and consists of an access hall, living + dining room, a corridor to access the bathroom, a kitchen with pantry, the stairs to access the first floor and an outside terrace.

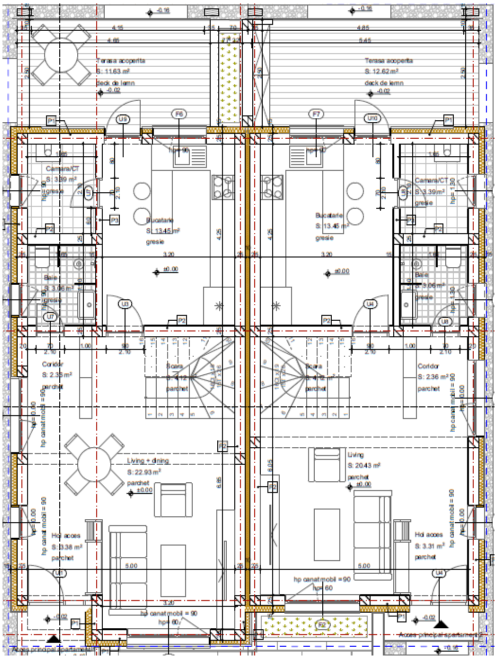

Figure 1. Ground floor

The first floor is also identical for both apartments and consists of 2 bedrooms with 2 dressings, a hall and a bathroom.

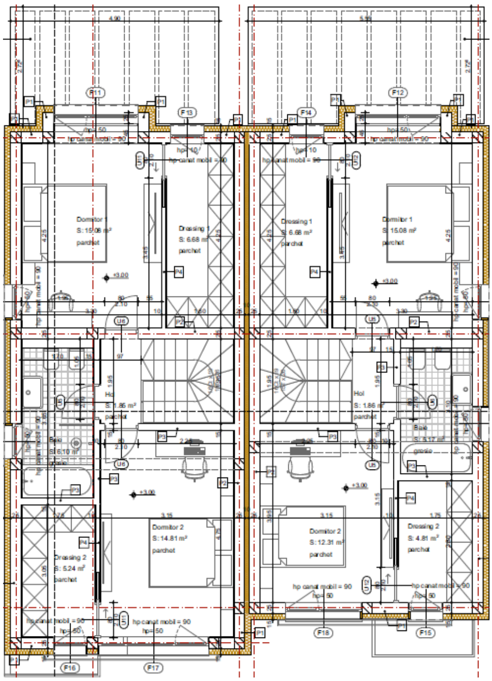

Figure 2. First floor

In order to realize the energy simulation, the two types of roofs need to be defined.
The first one is the flat roof (Figure 3). This type of roof has started to be used quite often in recent years in Romania because it offers the house a modern look. The component layers of this type of roof are (in order from inside to outside as well as heat transfer is realised):

- washable paint;
- lime-based plaster 1 cm;
- reinforced concrete floor 13 cm;
- bituminous vapor barrier with integrated diffusion layer;
- expanded polystyrene - EPS 120 20 cm;
- separating film - polyethylene film;
- slope extruded polystyrene 0.5-1.8% EPS 120 min. 3 cm;
- polymeric membrane for ballasted roof waterproofing;
- separation layer, geotextile, 200 g/m^2;
- protective layer - gravel 8-16 mm, min. 8 cm.

Even if it has an impact on the thermal transmittance, the slope extruded polystyrene it is not used as a thermal insulation, its purpose is technological, to achieve the necessary slope.

Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

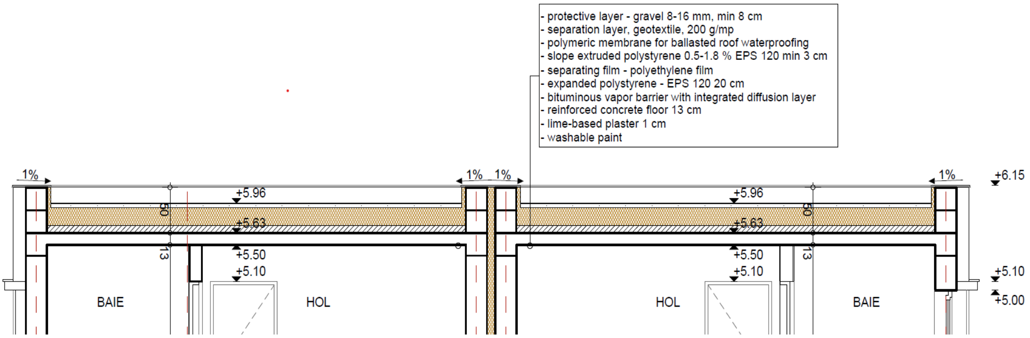

Figure 3. Section from flat roof

The second one is the pitched roof (Figure 4). This type of roof is the classic one and was used to build houses for centuries. The component layers of this type of roof are (in order from inside to outside as well as heat transfer is realised):

- rafters 10 x 15 cm;
- wooden board 2.5 cm;
- anti-condensation foil;
- longitudinal bar 3 x 5 cm;
- transverse bar 3 x 5 cm;
- ceramic tile.

Even if this are the components of the pitched roof, when the energy simulation is realized, we will consider the floor above the last level with its component layers (in order from inside to outside as well as heat transfer is realised):

- washable paint;
- lime-based plaster 1 cm;
- reinforced concrete floor 13 cm;
- polystyrene 20 cm.

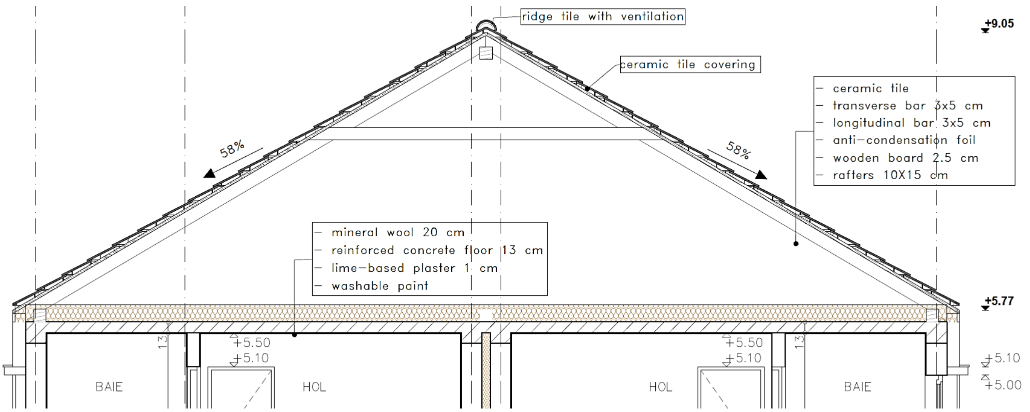

Figure 4. Section from pitched roof

RESULTS AND DISCUSSIONS

The aim of the current study is to do determine if there is a difference for heating energy demand and investment cost between the two types of roofs. Using the simulation software, the calculation for the heating energy demand of the building for each type of roof was realized.

The only difference between the two cases is the thermal transmittance for the last floor slab (lower is better).

The building envelope is described in the Table 1. The surface of each element calculated for every cardinal orientation and the material of each component layer with its thickness are presented.

Table 1. Building envelope components

	Description		Area [m²]	Layers (i-o)	
				Material	Thickness [m]
Exterior walls	N-V	Masonry walls	53.99	Lime-based plaster	0.01
	N-E		44.265	Masonry	0.25
	S-V		44.31	Mineral wool	0.15
	S-E		52.185	Lime-based plaster	0.005
Ground floor slab	-	Reinforced concrete slab	117.38	Floor tiles	0.01
				Cement mortar	0.05
				Polystyrene	0.05
				Reinforced concrete	0.1
				Polystyrene	0.1
Exterior w/d	N-V	PVC windows/doors with 3 glass layers and gas	11.46	PVC and glass	-
	N-E		17.06		
	S-V		21.14		
	S-E		9.14		
Last floor slab flat roof	-	Reinforced concrete slab	118.66	Lime-based plaster	0.01
				Reinforced concrete	0.13
				Polystyrene	0.2
				Slope polystyrene	0.03-0.20
				Gravel	0.08
Last floor slab pitched roof	-	Reinforced concrete slab	118.66	Lime-based plaster	0.01
				Reinforced concrete	0.13
				Polystyrene	0.2

To make the calculation of the energy required for heating the house, the thermal conductivity of envelope materials needs to be known.

The thermal conductivity of component materials is presented in the Table 2.

Table 2. Thermal conductivity of last floor slab

	Description	Material	Thickness [m]	Thermal conductivity [W/mK]	Thermal transmittance [W/m²K]
Last floor slab flat roof	Reinforced concrete slab	Cement mortar	0.01	0.6	0.11
		Reinforced concrete	0.13	1.7	
		Polystyrene	0.2	0.029	
		Slope polystyrene	0.03-0.20	0.029	
		Gravel	0.08	0.8	
Last floor slab pitched roof	Reinforced concrete slab	Cement mortar	0.01	0.6	0.2
		Reinforced concrete	0.13	1.7	
		Polystyrene	0.2	0.029	

As we can see, the last floor slab represents 24% of the total area of building envelope. This means that it has a major effect on heating energy demand. The thermal transmittance of last floor slab for flat roof is 0.11 W/m^{2}K and for pitched roof is 0.20, so a difference of 83%. Even if between the thermal transmittances the difference is almost double, the heating energy demand in case of flat roof is 71.10 kWh/m^{2}year and in case of pitched roof is 76.04 kWh/m^{2}year (Table 3).

Table 3. Heating energy demand

Roof type	Thermal transmittance [W/m^{2}K]	Heating energy demand [kWh/m^{2}year]
Flat	0.11	71.10
Pitched	0.20	76.04

So, for heating energy demand there is only a difference of 7% between the two types of roofs. This is due to the fact that in case of pitched roof, the last floor slab is not in direct contact with the outside because between the roof itself and last floor slab a buffer zone is created. Apart from the heating energy demand, the investment costs must be considered. To highlight the difference between the roofs we will compare only the cost for the roof itself, not for the entire building. The total costs for the roofs are composed of:

- materials for roof structure;
- materials for thermal insulation;
- materials for waterproofing;
- materials for roof covering;
- labour costs.

The costs are not estimated, they are current market costs. For the flat roof, the investment cost is 12.900 euro. For the pitched roof, the investment cost is 19.130 euro. So, there is a difference between the two types of roofs of 48%. This means that the pitched roof is with 6230 euro more expensive than the flat roof.

CONCLUSIONS

A very important aspect of future sustainability is that buildings are in need to meet higher performance requirements, for reaching a positive balance between the produced and required energy (Economidou et al., 2020).

With the help of an energy simulation that we made for the building, we showed that the heating energy demand differ only for 7% between the flat roof and pitched roof.

In terms of investment costs, things are a little different. The financial analysis shows that the flat roof is more economical.

So, the flat roof has a better impact on the heating energy demand of the building and is also cheaper to be developed. But it is not all about costs, because in case of buildings roofs the architectural factor also plays an important role.

Thus, the decision to choose the type of roof is not always based on energy considerations.

REFERENCES

Abuseif, M., & Gou, Z. (2018). A review of roofing methods: Construction features, heat reduction, payback period and climatic responsiveness. *Energies, 11*(11). 3196.

Charisi, S. (2017). The role of the building envelope in achieving nearly-zero energy buildings (nZEBs). *Procedia Environmental Sciences, 38*. 115-120.

Economidou, M., Todeschi, V., Bertoldi, P., D'Agostino, D., Zangheri, P., & Castellazzi, L. (2020). Review of 50 years of EU energy efficiency policies for buildings. *Energy and Buildings, 225*. 110322.

He, Q., Ng, S. T., Hossain, M. U., & Skitmore, M. (2019). Energy-efficient window retrofit for high-rise residential buildings in different climatic zones of China. *Sustainability, 11*(22). 6473.

Kaynakli, O. (2012). A review of the economical and optimum thermal insulation thickness for building applications. *Renewable and Sustainable Energy Reviews, 16*(1). 415-425.

Loukaidou, K., Michopoulos, A., & Zachariadis, T. (2017). Nearly-zero energy buildings: Cost-optimal analysis of building envelope characteristics. *Procedia Environmental Sciences, 38*. 20-27.

Maduta, C., Giulia, M., & Paolo, B. (2022). Towards a decarbonised building stock by 2050: The meaning and the role of zero emission buildings (ZEBs) in Europe. *Energy Strategy Reviews, 44*. 101009.

Pescari, S., Stoian, V. A., Merea, M., & Pitroaca, A. (2022). Comparison Study of the Heating Energy Demand for a Multi-Storey Residential Building in Romania Using Steady-State and Dynamic Methods. *Buildings, 12*(8). 124.

Stachera, A., Stolarski, A., Owczarek, M., & Telejko, M. (2023). A Method of Multi-Criteria Assessment of the Building Energy Consumption. *Energies, 16*(1). 183.

Zhang, S., Sun, P., & Sun, E.P. (2022). Research on energy saving of small public building envelope system. *Energy Reports, 8*. 559-565.

Zhang, D., Ding, Y., Wang, Y., & Fan, L. (2022). Towards ultra-low energy consumption buildings: Implementation path strategy based on practical effects in China. *Energy for Sustainable Development, 70*. 537-548.