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AN EMPIRICAL ANALYSIS OF THE LITHUANIAN AND POLISH NORMATIVE REQUIREMENTS AND THEIR INFLUENCE ON THE PAYBACK OF A THERMO-INSULATION LAYER OF AN EXTERNAL WALL DETAIL

ANALIZA LITEWSKICH I POLSKICH WYMAGAŃ OCHRONY CIEPLNEJ ORAZ ICH WPŁYWU NA CZAS ZWROTU TERMOIZOLACJI ŚCIANY ZEWNĘTRZNEJ

A b s t r a c t

The article provides the empirical analysis of thermo-insulation layer thickness (expanded polystyrene – EPS70) of the typical wall detail and its investment payback period in the traditional new construction single-apartment residential and net-zero energy building. On the basis of the results a simple payback period was calculated. Geographic region of Lithuania and Poland was chosen as the research object. The research results are important for building investors, designers, also for the auditors and experts of buildings energy consumption.

Keywords: wall, thermo-insulation thicknesses, payback period

S t r e s z c z e n i e

Artykuł stanowi empiryczną analizę grubości warstwy termoizolacji (styropian – EPS70) i okresu zwrotu inwestycji typowego dla nowo wznoszonych jednorodzinnych budynków mieszkalnych i budynków zero-energetycznych rozwiązania przekroju ściany zewnętrznej. Głównym celem było uzyskanie ochrony cieplnej lepszej niż wartości wymagane w przepisach litewskich i polskich oraz zgodnej ze standardami europejskimi. Uzyskane i zaprezentowane wyniki mogą być istotne dla inwestorów, projektantów, a także audytorów i ekspertów zajmujących się zużyciem energii w budynkach.

Słowa kluczowe: ściana, grubość termoizolacji, czas zwrotu

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1. Introduction

All European Union Member States have to ensure that all newly constructed buildings will have to be nearly zero-energy consumption buildings since 31 December 2020, according to requirements of the European Directive 2010/31/EU. A 5-year period is set to achieve this aim [5].

Single-apartment residential buildings with almost unconsumed energy (nearly of zero-energy) are those of very high-energy efficiency where energy consumption equals to almost zero or is very low. These buildings mostly consume the energy produced from renewable sources on site or nearby [1, 2].

According to the requirements for legal acts passed in the Republic of Lithuania and considering European standards – the buildings of classes B, A, A+ and higher can be called low-energy buildings (BUILD UP skills – Lithuania) [3]. Effectively designed and built buildings with almost unconsumed energy (A++ class) is a big challenge not only for Lithuania but also for Poland.

Foreign scientists experience and analysis on this problem is limited. Therefore, scientific achievements in this direction are necessary and timely, this emphasize in articles.

The buildings sector has a large potential for energy savings, because about 40% of the total amount of energy is consumed in this field in the United States or Europe, and nearly 30% in China [4].

Energy saving is an important part of the Energy Policies of the European Union and the Republic of Lithuania and Poland.

The study is aimed at developing correlation functions and determining links between the thickness of the thermal isolation layer of the wall (expanded polystyrene – EPS70) and its payback time according to the energy performance class of the building and the geographical area of building construction.

2. Object description

As for Lithuania, according to the currently valid normative requirements and provisions of STR 2.01.09:2012 Energy Performance of Buildings. Certification of Energy Performance [7], buildings are classified and divided into 9 energy efficiency classes, including A++, A+, A, B, C, D, E, F and G (Fig. 1a). The efficiency of energy consumption in the lately erected buildings (building parts) in Lithuania must not be lower than energy performance class "B" by 2016.

To make buildings more energy efficient, minimum energy performance requirements have been raised since 2007 in order to achieve A++ class requirements for buildings with almost unconsumed energy (nearly of zero-energy) performance.

A methodology for calculating the energy performance of a building in Poland is specified in normative documents (Dz. U. poz. 1200, Dz. U. poz. 376 and Dz. U. 75, Poz. 690). According to these documents, the buildings are not grouped in energy performance classes. Their estimated annual energy inputs per one square meter of the useful area of a building is calculated (Fig. 1b).

The research object of the study is the relations between the thickness of the thermo-insulation layer of the typical details of the wall (see Fig. 2) and its simple payback time. The wall was evenly insulated with expanded polystyrene (EPS70) foam having the declared value of the thermal conductivity coefficient (in this study – λ_{dec} = 0.039 W/(m·K)).

In order to find out the influence of climate and a geographic location on the thickness of the thermo-insulation layer, calculations in 3 Lithuanian and 5 Polish cities were performed. The average outside air temperature discussed in this study has been adopted according to data on (Table 2).

a) b)

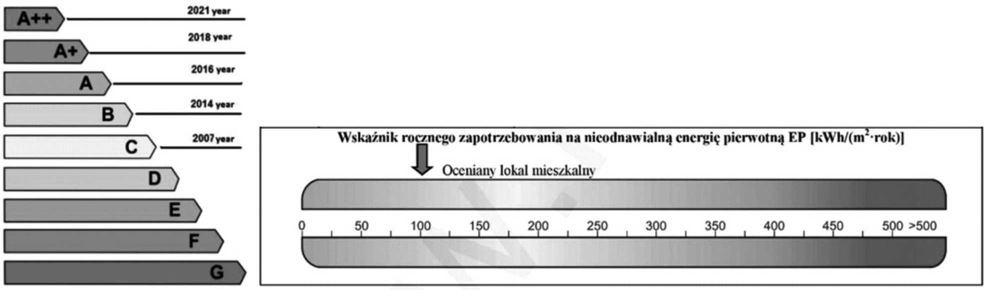

Fig. 1. Classification of energy efficiency of buildings: 1a – Lithuania – classes of energy efficiency (STR 2.01.09:2012); 1b – Poland – graphic method. Source: (Dz. U. Poz. 376)

Normative requirements for the wall partitions of residential buildings of the one and two-room apartment have been investigated in the study (Table 1).

Table 1

Normative value of the thermal transmittance coefficient of walls in residential buildings $U_{N.w}$, W/(m²·K)

Year (PL)/Energy performance class (LT)	In Poland	In Lithuania
2014 (PL)/B (LT)	0,25·κ	0,20·κ
2017 (PL)/ A (LT)	0,23·κ	0,12·κ
2021 (PL)/A++ (LT)	0,20·κ	0,10·κ
Multiplier κ = 20/(θi – θe), where θi – indoor temperature during the heating season is equal to θi = 20°C; θe – the average outside air temperature during the heating season (Table 3).		

The problem is that the geographic region of Lithuania in technical documents is evaluated as one climatic region, with an average outside air temperature of +0.6° during the heating season [2]. Different outside air temperature can be observed in different climatic zones in Lithuania and Poland (Table 2), and therefore, for using correlation dependence functions, a calculation solution to the thickness of the thermo-insulation layer (EPS70) of the typical details of the wall will be presented in this work.

The calculation methodology for the heat transfer coefficient of partitions and correlation dependence are further analysed. Then, on the basis of the obtained results simple payback periods are estimated.

Table 2

The average outside air temperature during the heating season (Source: The Norm on Construction of the Republic of Lithuania RSN 156-94)

Location	The average temperature, θ_e,°C	Duration in days	Location	The average temperature, θ_e,°C	Duration in days
Gdańsk	–0.05	242	Suwałki	–2.54	252
Poznań	–0.67	227	Klaipeda	1.9	214
Warszawa	–0.63	222	Kaunas	0.7	219
Białystok	–1.9	232	Vilnius	0.2	225

3. Calculation methodology

As for this study, general data and formulas for external wall partitions were taken from document STR 2.01.09:2012 *Energy Performance of Buildings. Certification of Energy Performance*. This procedure is also enshrined in Polish normative acts [6, 8, 9, 10].

The total heat transfer coefficient U_w (W/(m^2·K)) of the external wall (Picture 2) can be calculated as follows (Eq. 1):

$$U_w = \frac{1}{R_t} = \frac{1}{R_{si} + R_{s1} + R_{se}} \tag{1}$$

where:
R_{si} – the thermal resistance of the internal surface of the wall (m^2·K/W);
R_{se} – the thermal resistance of the external surface of the wall (m^2·K/W);
R_{s1} – the sum of the thermal resistance of wall layers (m^2·K/W);
R_t – the total thermal resistance of external wall construction (m^2·K/W).

The main verification condition is the heat transfer coefficient of the external wall partition that must satisfy normative requirements (Eq. 2):

$$U_w \leq U_{N.w} \tag{2}$$

where:
U_w – the design value of heat transfer coefficient of the wall partition W/(m^2·K) that directly depends on the investigated object, i.e. thermo-insulation (EPS70) thickness (see Fig. 2);
$U_{N.w}$ – the normative heat transfer coefficient of the wall W/(m^2·K) depending on energy efficiency class (see Table 1) and the average outside air temperature during the heating season (Table 2).

When the required thickness of the thermo-insulation layer is obtained, the period of simple materials and salary (investment) payback is calculated (Eq. 3):

$$PS = \frac{I_0}{\Delta S} \tag{3}$$

where:
I_0 – the amount of investment to additional insulation, €/m^2;
ΔS – annual savings, first year cost, €/(m^2·years).

The annual savings are calculated according to the following expression (Eq. 4):

$$\Delta S = \left(\frac{\Delta U \cdot \Delta\theta \cdot t \cdot 24}{1000} \right) \cdot E; \tag{4}$$

where:
$\Delta U = U_1 - U_2$ is the difference value of heat transfer coefficients of the wall (before U_1 and after U_2 additional insulation) W/(m^2·K);
$\Delta\theta$ – the difference of inside and outside air temperature during the heating season, °C;
t – the duration of the heating season, days (Table 3);
E – heat energy costs, €/kWh.

4. Research model

A research model has been created for determining correlation functions. The solutions to the designed model cover [2]:

1. For the purpose of calculations, the typical details of the wall of the residential building of one and two room-apartment were accepted (Table 4).
2. The thermal resistance of the external surface of the wall is R_{se} = 0.04 m^2·K/W; the thermal resistance of the internal surface of the wall is R_{si} = 0.13 m^2·K/W.
3. The adhesive mortar layer was adopted as a thin layer R_q = 0.04 (m^2·K)/W respectively, according to technical regulations on construction STR 2.01.09:2012.
4. The expanded polystyrene (EPS70) foam was used as insulation according to document ST 124555837.01:2013 *Expanded Polystyrene Foam Thermal Insulation for Building Partitions* (Fig. 2). The declared value of heat conductivity coefficient is λ_D = 0.039 W/(m·K). The design value of the accepted heat conductivity coefficient is 0.041 W/(m·K) (according to document STR 2.01.03:2009).
5. Normative values of the heat transfer coefficient of the wall were accepted according to requirements for technical regulations on construction STR 2.01.09:2012 assessing temperature adjustment κ = 1. Effect of the location assessed through temperature adjustment $\kappa = 20/(20 - \theta_e)$, when θ_e accepted in Table 2.
6. Masonry wall – autoclaved aerated concrete blocks, specific weight – 500 kg/m^3, thickness – 250 mm; λ_{ds} = 0.153 W/(m·K).

7. Thin-reinforced rendering thickness – 5 mm; surface finishing – 15 mm; λ_{ds} = 0.8 W/(m·K).
8. The price of insulation materials (EPS70) and a salary of 47.47 €/m^3 were accepted.
9. Thermal energy cost was accepted (the average Lithuanian price of central heating systems in 2014) E = 0.0724 €/kWh.

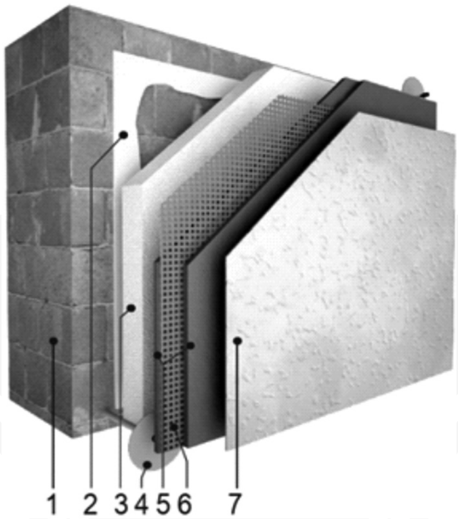

Fig. 2. Details of the wall. Source: (ST 124555837.01:2013). Research object – (3) the thickness of the thermo-insulation layer EPS70 of the wall, mm (for layers see Table 4)

Research calculations were performed using the same model/element and building design solutions, changing only climatic data.

Table 3

The layers of the details of the external wall

No.	Wall layer	Thickness, mm
*	Surface finishing	15
1	Autoclaved aerated concrete blocks, (500 kg/m^3)	250
2	Adhesive mortar layer	5
3	Expanded polystyrene (EPS70) foam	**90–330**
4	Anchor with plastic nail	–
5	Adhesive mortar coated with masonry sealer	5
6	Reinforcing mesh	
7	Decorative coat	

5. Research results

The required thickness of the thermo-insulation layer (EPS70) of the sample of a typical wall was calculated according to the methodology for normative requirements for energy efficiency. As provided in Table 5, the final thickness of the wall was calculated using the approximation method of checking the condition of Eq. (2) and changing climatic data.

Table 4

The thickness of the calculated thermo–insulation layer (EPS70) (in accordance with regulatory requirements for external walls)

Year (PL) /Energy performance class (LT)	Thickness of the thermo–insulation (EPS70) layer, mm								Difference, t
	Gdańsk	Warszawa	Poznań	Białystok	Suwałki	Klaipeda	Kaunas	Vilnius	
1	2	3	4	5	6	7	8	9	10
2014 (PL)/ B (LT)	90	95	95	105	110	110	130	130	1.44
2017 (PL)/ A (LT)	105	110	110	120	125	240	260	270	2.57
2021 (PL)/ A++ (LT)	130	135	140	150	155	300	320	330	2.54
Difference, t	1.44	1.42	1.47	1.43	1.41	2.73	2.46	2.54	

The thickness of the thermal insulation layer increases proportionally with a rise in energy efficiency class using traditional insulation materials (in this study – EPS70) for the thermal insulation of external wall partitions. The normative thickness of the thermal insulation layer increases 2.73 times for buildings with almost unconsumed energy (A++ class), compared with the currently valid minimum requirements pertaining to energy efficiency classes "B", as shown in Table 4.

The simple payback period of the thermo–insulation layer (EPS70) of the wall was estimated using formula presented in Eq. 3. The Lithuanian requirements is the reference level to which payback is applied. The research results are presented in Table 5.

Table 5

The calculated simple payback period of the thermo–insulation layer of the wall (EPS70)

Year (PL)/ Energy performance class (LT)	Simple payback period, years								Difference, t
	Gdańsk	Warszawa	Poznań	Białystok	Suwałki	Klaipeda	Kaunas	Vilnius	
1	2	3	4	5	6	7	8	9	10
2014 (PL)/B (LT)	2.3	2.5	2.6	2.5	2.3	3.3	3.5	3.2	1.44
2017 (PL)/ A (LT)	2.6	2.8	2.8	2.7	2.4	5.7	5.6	5.4	2.57
2021 (PL)/A++ (LT)	2.9	3.3	3.2	3.1	2.8	6.8	6.5	6.3	2.54
Difference, t	1.25	1.30	1.24	1.25	1.25	2.06	1.86	1.96	

6. Conclusions and implications

– The carried out analysis shows that the variation of the thickness of the thermo-insulation layer of the typical details of the wall depends on energy efficiency class and the type of the geographical location.
– Comparison of the Lithuanian and Polish standard requirements for the energy efficiency of buildings shows that the required thickness of the thermal insulation layer (EPS70) of the typical details of the wall varies and may increase by 2.57 times.
– The evaluation of the buildings of the same energy efficiency class in different climatic zones of Lithuania and Poland has disclosed that the thinnest thermal insulation layer of wall partitions is required in Gdańsk region, while the thickest one – in Vilnius. The greatest influence of fluctuations in climate has been noticed on the buildings of energy efficiency class A++. In this category, the required thickness of the thermal insulation layer (EPS70) pertaining to the wall varies by 20 cm between the warmest and coldest regions of Lithuania and Poland.
– According to the conducted research, the longest payback period of contributed funds (price of thermal insulation materials) is achieved within the period of up to 6.8 years in the city of Klaipeda.

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