

BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI

Publicat de

Universitatea Tehnică „Gheorghe Asachi” din Iași

Volumul 68 (72), Numărul 1, 2022

Secția

CONSTRUCȚII. ARHITECTURĂ

DOI: 10.2478/bipca-2022-0002



THERMAL REHABILITATION OF EXTERNAL WALLS – CASE STUDY

BY

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Received: March 1, 2022

Accepted for publication: May 30, 2023

Abstract. Both at national and international level, the present-day trends relate to the development of high-performance enclosing and insulation systems that make use of modern thermo-energetic rehabilitation methods.

Thermal rehabilitation works for the envelope of a building or for the building elements forming the envelope concern the diminishing of the heat losses by increasing the thermal resistances of the enclosing elements and limiting air infiltrations through glazed elements and joints.

In most Western European countries, national programmes aiming at the thermal protection of the buildings have been developed. The projects ran in gradual stages, starting after the energy crisis in 1973 and 1979, the outcome being a reduction of the energy consumption.

According to the Energy Performance of Buildings Directive issued by the European Commission, at present, buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy-related greenhouse gas emissions (https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en).

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In the paper, a case study is presented, analysed from the point of view of energy efficiency through a new software for computing developed by the author called REBUILD, which leads to the choice of appropriate solutions for the thermal rehabilitation of an element of the building envelope. The recommended solution after the study is intended to bring the structure back to its optimal energy performance and to abide by the current regulations.

Keywords: renovation, envelope, building, thermal performances.

1. Introduction

Before the world energy crisis (1973), regulations in constructions did not contain recommendations regarding energy consumptions and were focused upon:

- a) avoiding the occurrence of the condensation phenomenon on the interior surface of the envelope element.
- b) achieving a constant interior air temperature.

Later on, the concern for improving the thermal protection degree for the elements of the building envelope underwent a remarkable development, the purpose being to optimize energy saving and also to fulfil performance requirements regarding thermal comfort. (Stanca S. E, 2018)

After 1990, the issue of mitigating energy consumption began to be connected with environment protection and air quality demands.

2. Thermal protection level in elements of the envelope

The thermal insulation level is influenced by the minimum values of corrected thermal resistances, standardized values for construction elements (exterior walls, terraces, floors over the basement). As can be seen these values are constantly changing, being adapted to global requirements, Table 1.

Table 1
The minimum values of corrected thermal resistances for construction elements

The normative act		R [$\text{m}^2\text{K}/\text{W}$]			R' [$\text{m}^2\text{K}/\text{W}$]		
Period of application		Exterior walls	Floors		Exterior walls	Floors	
			Terrace Loft floor slabs	Over unheated basement		Terrace Loft floor slabs	Slabs over unheated basements
STAS 6472-61	1962- 1968	0.76	0.96	0.82	-	-	-
STAS 6477-68	1969- 1975	0.80	1.02	0.87	0.60	-	-

STAS 6472-75	1976- 1984	0.80	1.02	0.78	0.60	-	-
STAS 6472-84 NP 15-84	1985- 1987	0.76 1.20	0.87 1.55	0.56 1.08	0.76 1.20	0.70 1.55	0.56 1.08
STAS 6472-84 NP 15-87	1988- 1989	0.76 1.20	0.87 1.55	1.56 1.08	0.76 1.20	0.87 1.55	0.56 1.08
STAS 6472-89 NP 15-87	1990- 1997	1.00 1.20	1.24 1.5	0.67 1.08	1.00 1.20	1.24 1.55	0.67 1.08
C107/3- 2005	1997- 2005	-	-	-	1.40	3.00	1.65
Mc 001- 2006 Order 2641/2017	2005- 2023	-	-	-	1.8	5.00	2.90
Mc 001- 2022	present						

3. Solutions for the energy rehabilitation of a walls

The goal of thermal rehabilitation is to improve the thermal comfort within a building and reduce its energy usage.

The energy rehabilitation and modernization interventions in a building are, intervention with the aim of reducing the building's own heat needs.

Improving the thermal insulation of an existing building to decrease the dissipated thermal flow by conduction through the building envelope towards the external environment:

- Improving the thermal insulation of the opaque horizontal construction elements: terrace, loft, floor over the basement;
- Improving the thermal insulation of the vertical construction elements on the exterior and the interior of the building;
- Improving of glazed construction elements.

Improving the air tightness in order to diminish or remove disturbing infiltrations (mobile elements joints or ruling blinders) which have negative effects upon the building:

- tightening the mobile elements joints from the heated area;
- sealing the mobile elements joints from the unheated area.

The savings in energy consumption indispensable for a healthy and comfortable interior environment can be achieved with passive measures, associated to minimal energy consumption, integrated in the building architectural and constructive design.

Passive measures associated with minimal energy consumption in a building include:

- *Improved insulation*: ensuring that the building is adequately insulated and that windows and doors are sealed properly to prevent heat loss;
- *Natural Ventilation*: making use of natural ventilation techniques such as operable windows, passive stack ventilation and wind cowls to reduce energy consumption from mechanical ventilation systems;
- *Lighting*: utilizing natural light as much as possible and installing energy-efficient lighting fixtures;
- *Solar Energy*: installing solar panels to generate electricity and/or hot water for the building;
- *Use of Renewable Energy Sources*: utilizing renewable energy sources such as wind, geothermal, and biomass to reduce energy consumption from traditional sources;
- *Heating and Cooling Systems*: installing more efficient heating and cooling systems to reduce energy consumption;
- *Smart Technology*: installing sensors and controllers to ensure that systems are only running when necessary.

3.1 The insulation of the facades/external walls of a building is a solution that not only substantially contributes to reducing heat losses, but also gives an improved appearance to the building. The solution has a number of advantages/disadvantages illustrated in Table. 2:

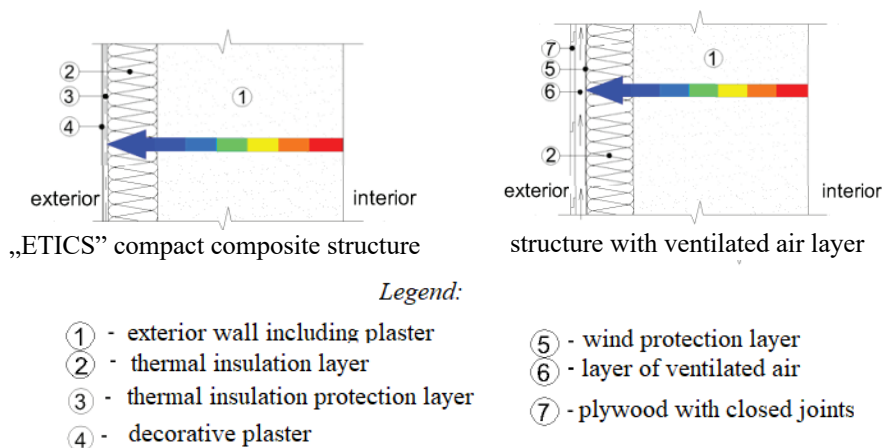
Table 2
The insulation of the facades/external walls of a building

Advantages	Disadvantages
○ <i>Improved energy efficiency</i>: Insulated facades help keep the building warm in winter and cool in summer, reducing energy consumption and costs; ○ <i>Increased comfort</i>: Insulated walls reduce drafts and air infiltration, improving the overall comfort level of a building; ○ <i>Reduced sound</i>: Insulated facades can reduce the noise transmission from outside, making the interior more peaceful; ○ <i>Improved indoor air quality</i>: Insulated facades can help keep out pollutants, dust, and other allergens, providing improved indoor air quality;	○ <i>Increased costs</i>: Insulating the exterior walls can be expensive, depending on the type of insulation used; ○ <i>Structural changes</i>: Making structural changes to the exterior walls for insulation can be difficult and costly; ○ <i>Moisture issues</i>: Exterior wall insulation can trap moisture between the insulation and the wall, leading to dampness in the walls and potential health problems; ○ <i>Loss of natural ventilation</i>: Adding insulation to the exterior walls can reduce the amount of natural ventilation and air movement in the building;

Advantages	Disadvantages
○ <i>Increased durability</i>: Insulated facades can help protect a building from the elements, increasing its lifespan and reducing the need for repairs and maintenance.	○ <i>Heat build-up</i>: Insulation can trap heat in the building, resulting in higher temperatures and higher cooling costs.

The insulation of exterior walls is an important stage in the renovation of a building, this process can be carried out by several methods and different building materials can be used: polystyrene, mineral wool, polyurethane foam, environmentally friendly materials (cork, hemp, wool).

Basic solutions for thermal rehabilitation of the exterior walls, where the thermal insulation layer is placed on the outside, are presented in Figure 1 [SC007 – 2013].



Vertical sections

Fig. 1 – Basic solutions for the thermal rehabilitation of exterior walls in the current field [SC007 – 2013].

3.2 Inside insulation of an external wall

An alternative for the thermal insulation of the external walls consists in positioning the thermal insulation layer on the inside of the walls, as this is an effective way to keep the heat inside the house. The insulation layer is usually composed of a bonding layer, a thermal insulation layer made from a material such as basaltic wool or polystyrene, and a vapour control layer. This type of insulation is particularly suitable for older buildings, where the external walls cannot be easily replaced. Insulation detail, interior thermal insulation layer structure in Figure 2 [SC007 – 2013].

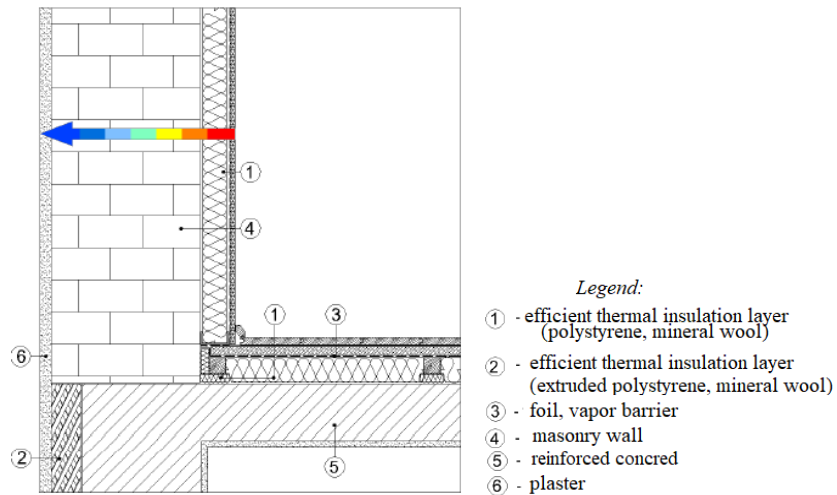


Fig. 2 – Insulation detail, interior thermal insulation layer structure, vertical section, [SC007 – 2013].

The solution has a number of advantages/disadvantages illustrated in Table. 3:

Table 3

The thermal insulation of the walls including the thermal insulation layer applied on the inner face of the wall

Advantages	Disadvantages
○ Smaller expenses than with external thermal insulation; ○ Smaller interval and value for investment recovery; ○ The architectural appearance of the buildings is not affected, a very important aspect for historical and architectural buildings modernization; ○ The modernization is simple, with no special assembling equipment, with regard to the mounting process; ○ Maintenance is more accessible than when applying insulation on the exterior of the building; ○ As modernization works are carried out inside the building, bad weather conditions do not represent an obstacle.	○ The outer walls remain cold during winter and increase the risk of condensation in the wall; ○ The interior space of the room is reduced; ○ A major disadvantage of positioning the thermal insulation layer on the inside of the walls is that it can create thermal bridges. Thermal bridges are areas of the wall where heat can more easily move through, such as where the wall meets the floor or window frames. If the insulation layer is on the inside of the wall, it may not be able to properly insulate these areas, leading to decreased energy efficiency and increased energy costs.

4. Case study

The building under investigation dates back to the year 1936, consists of a ground floor and 1 additional floor. The load-bearing walls are made of brick masonry and measure 50 cm thick on the outside and 40 cm thick on the inside, Figure 3 (Stanca S. E, 2021).

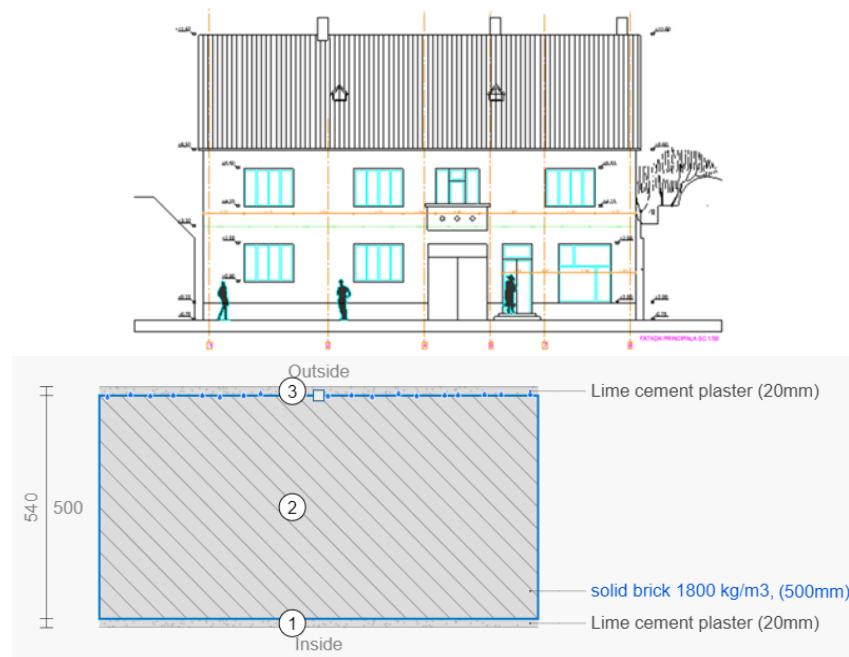


Fig. 3 – The analyzed building, exterior wall detail.

The thermal rehabilitation works for the component elements of the envelope concern the reduction of heat loss by increasing the thermal resistances of the closing elements.

The determination and comparison of the values of the specific corrected thermal resistances R'_m with the minimal values of the thermal resistances R'_{min} for walls is made with the relationship (Mc 001-2022):

$$R'_m \geq R'_{min} [m^2 K/W] \quad (1)$$

The assessments were performed with the help of software for computing developed by the author called REBUILD. The REBUILD program was created as an application using Visual Studio Code is a source code editor developed by Microsoft for Windows. Through its module, the software allows to find out and compare the values of the specific corrected thermal resistances for the elements

that separate different spaces in the analysed functional unit with the minimum values of the thermal resistances specified in the norms.

If the values of the specific corrected thermal resistances R'_m , obtained from the calculation, do not comply with the above relationship, the values of the calculation parameters indicated in the image below will appear in a different colour, which indicates that the recommended wall is not satisfactory, Figure 4:

Thermal Evaluation
Outer wall of resistance

Interior plaster	Layer thickness d , [m]	0.02	$R_{si} = 0.125$ [mpK/W]
	Apparent density ρ [kg/mp]	1700	
	Thermal conductivity λ [W/mk]	0.87	
Masonry	Layer thickness d , [m]	0.5	$R_{se} = 0.042$ [mpK/W]
	Apparent density ρ [kg/mp]	1800	
	Thermal conductivity λ [W/mk]	0.80	
Thermal insulation	Layer thickness d , [m]	0.05	$R_m = R_{si} + \Sigma R_{sj} + R_{se}$
	Apparent density ρ [kg/mp]	20	
	Thermal conductivity λ [W/mk]	0.042	
Exterior plaster	Layer thickness d , [m]	0.02	$\Sigma R_{sj} = \Sigma d/\lambda$
	Apparent density ρ [kg/mp]	1700	
	Thermal conductivity λ [W/mk]	0.87	
			$R'_m = R_m \times r = 1.419683908$
			$R_{min}' = 1.8$ [mpK/W]
			$R'_m \geq R_{min}'$
			Evaluate



Fig. 4 – Values of the R'_m specific corrected thermal resistances (thermal insulation $d=0.05m$).

Since the share of thermal bridges for exterior walls is between 20% - 45%, in the calculations it is estimated a $\approx 30\%$ percentage of reduction.

The table below, Table 4 shows the characteristics of the materials that have been taken into account when calculating the R'_m specific corrected thermal resistance for the exterior wall. (<https://baumit.ro/products/componente-sisteme-termoizolante/polistiren-expandat-pentru-fatade/baumit-duotherm>, <https://www.rockwool.com/ro/produse-si-aplicatii/izolatie-pereti-exteriori/>, <https://www.isover.ro/products/isover-fassade>)

Table 4
Features of heat-insulating materials

Materials	Thickness (m)	Density (kg/m ³)	λ (W/mK)
Expanded polystyrene	0.05	20	0.042
	0.10		
	0.15		
Basaltic mineral wool	0.05	60	0.035
	0.10		
	0.15		
Cellulose fibers	0.05	60	0.038
	0.10		
	0.15		

In the figures below, three scenarios are presented, namely:

- Scenario 1 - thermal insulation layer of 0.05m (expanded polystyrene, basaltic mineral wool, cellulose fibers);
 - Scenario 2 - thermal insulation layer of 0.10m (expanded polystyrene, basaltic mineral wool, cellulose fibers);
 - Scenario 3 - thermal insulation layer of 0.15m (expanded polystyrene, basaltic mineral wool, cellulose fibers);
- which result in the choice of the appropriate solution thermal system to increase the energetic performance of this element of the building envelope

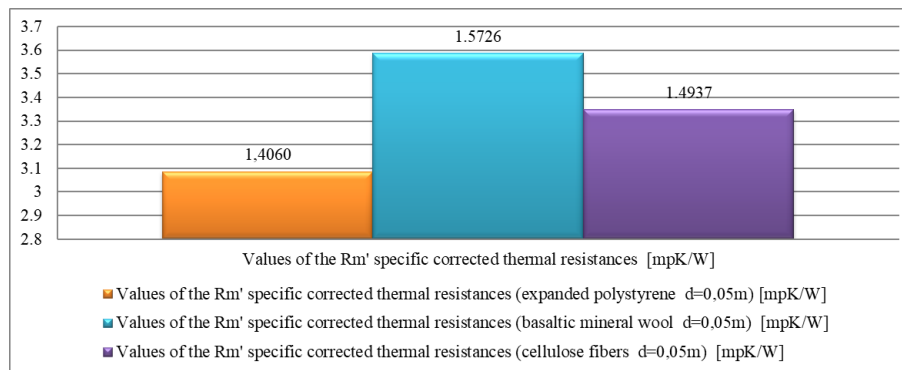


Fig.5 – Scenario 1 – thermal insulation layer of 0.05m.

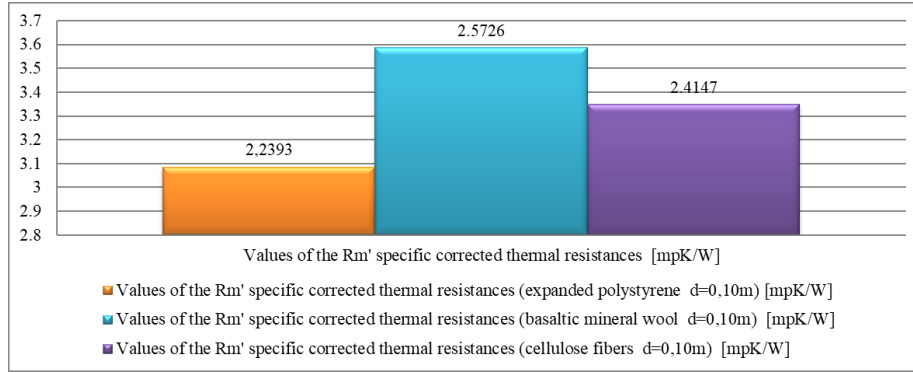


Fig.6 – Scenario 2 - thermal insulation layer of 0.10m.

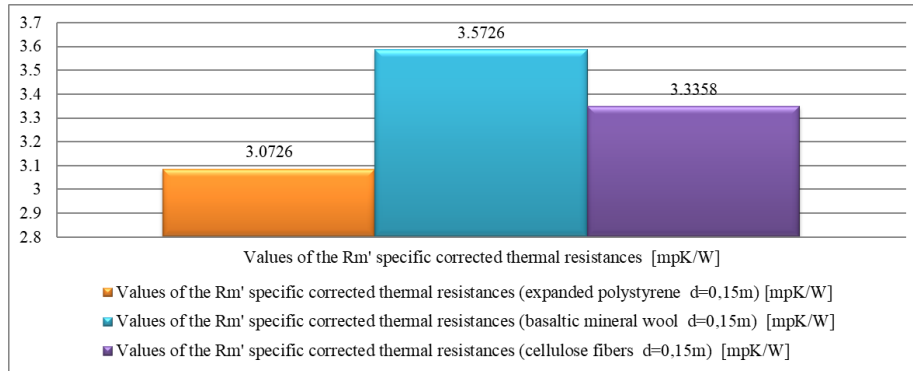


Fig.7 – Scenario 3 thermal insulation layer of 0.15m.

It can be seen from Figure 8 that, following the calculation, the thickness of the thermal insulation layers of 0.05m and 0.10m leads to a value of the R'_m specific corrected thermal resistance below the minimum R'_{min} value for walls provided by the methodology, which indicates that using this thickness for the thermal system is not satisfactory.

The figure below, Figure 9, shows the values of the specific corrected thermal resistances for the three scenarios analysed and the comparison of these values with the value indicated by the methodology for the studied element.

According to the calculations in the three scenarios, the best choice for the thermal rehabilitation of the exterior wall is to use 0.15m of basaltic mineral wool, Figure 10 ($R'_m = 3.5726 \text{ m}^2\text{K/W}$).

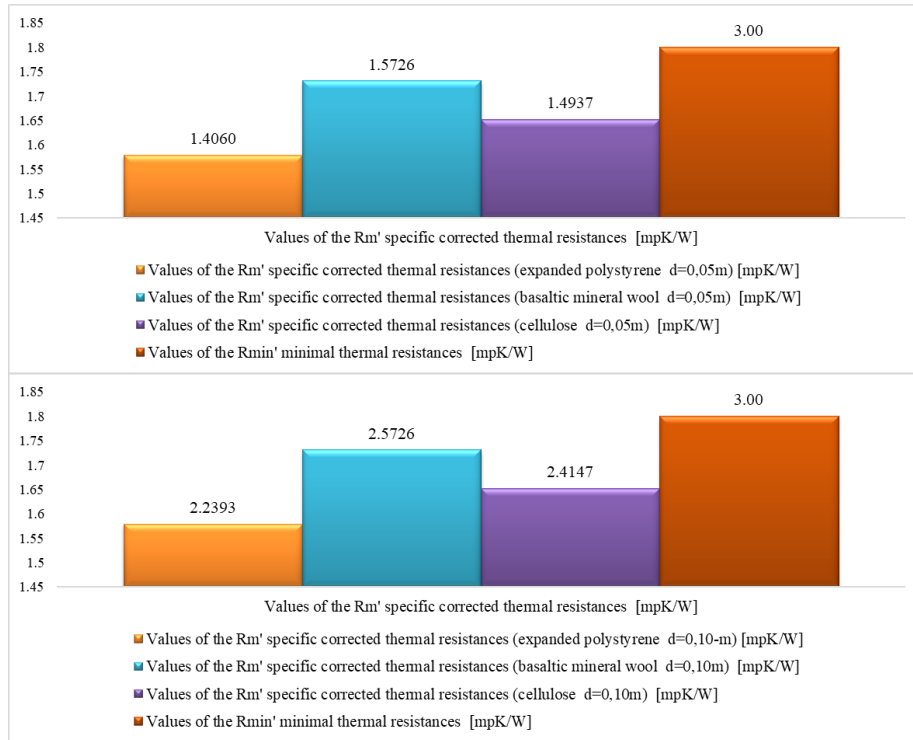


Fig.8 – Comparison of the values of the specific corrected thermal resistances with the value indicated by the methodology for the exterior wall, the thickness of the thermal insulation layer of 0.05m and 0.10m.

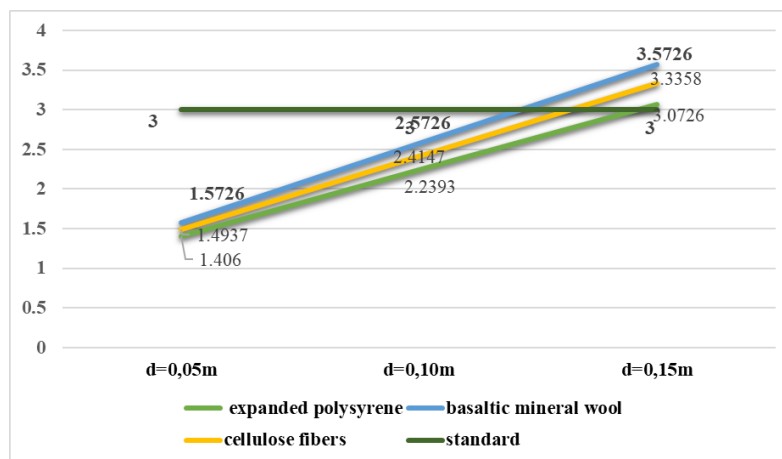


Fig.9 – The values of the specific corrected thermal resistances for the three scenarios analysed and the comparison of these values with those indicated by the methodology for the studied element.

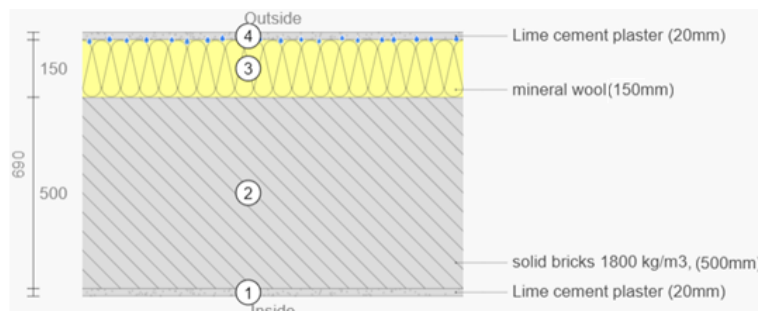


Fig.10 – Details of an external wall, the solution with 0.15 m of thermal insulation layer.

4. Conclusions

The determination and comparison of the values of the specific corrected thermal resistances with the minimum values of the thermal resistances for the walls according to the "Methodology for calculating the energy performance of buildings", Indicative Mc 001-2022, leads to the optimal thicknesses of the thermal insulation layers for these elements of the building envelope. The thermal properties of materials are essential to the building's thermal performance.

The solution with 0.15m of thermal insulation thickness, basalt mineral wool is the most favourable from the point of view of thermal protection and is meant to restore the structure to optimal operating parameters in accordance with the norms in force.

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REABILITAREA TERMICĂ A PEREȚILOR EXTERIORI – STUDIU DE CAZ

(Rezumat)

Tendențele curente în domeniu, atât pe plan internațional, cât și național, sunt cele ale dezvoltării unor sisteme performante de închidere și izolare care să întrebuițeze măsuri moderne de reabilitare termoeenergetică.

Lucrările de reabilitare termică a anvelopei clădirilor sau a elementelor de construcție componente ale anvelopei au în vedere reducerea pierderilor de căldură prin creșterea rezistențelor termice ale elementelor de închidere și prin limitarea infiltrațiilor de aer prin elementele vitrate și rosturi.

În majoritatea țărilor din Europa de Vest au fost desfășurate programe naționale având ca și obiectiv protecția termică a clădirilor. Proiectele au fost derulate în etape progresive, demarate după criza energetică din 1973 și cea din 1979, rezultatul a condus la o scădere continuă a consumului de energie.

În conformitate cu Directiva privind performanța energetică a clădirilor emisă de Comisia Europeană, în prezent, clădirile sunt responsabile pentru aproximativ 40 % din consumul de energie al UE și 36 % din emisiile de gaze cu efect de seră legate de energie (https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en).

În lucrare este prezentat un studiu de caz, analizat din punct de vedere al eficienței energetice printr-un nou software de calcul dezvoltat de autor, numit REBUILD, care conduce la alegerea soluțiilor adecvate pentru reabilitarea unui element al anvelopei clădirii. Soluția recomandată în urma studiului este menită să readucă structura la performanța energetică optimă și să respecte reglementările în vigoare.

