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VACUUM INSULATION MATERIAL OPTIM-R: THE FUTURE OF THERMAL INSULATION AND COMPARISON WITH STYROFOAM

By

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Abstract

The lack of energy, environmental pollution, and climate change caused by excessive and irrational energy consumption, as well as the constant rise in energy prices, are causes for concern and incentives to address this problem, all while preserving the environment.

Energy from renewable sources is significantly cheaper compared to energy from non-renewable sources. This paper analyzes the properties of Styrofoam and vacuum insulation material OPTIM-R with the aim of demonstrating that newer generation materials with extremely small dimensions can be more efficient than standard materials that have traditionally been used for insulation. The use of materials that are not harmful to the environment is preferred, as they prevent the emission of harmful gases and have a much longer lifespan compared to existing materials.

KEY WORDS: *Energy efficiency, insulation materials, environment, energy*

1. Introduction

The modern world is confronted with two major energy challenges: the shortage of energy and the insecurity of its supply, as well as environmental pollution and climate change resulting from excessive and irrational energy consumption. A few decades ago, energy efficiency and energy conservation were not regarded as significant issues, primarily because energy was both inexpensive and readily available. However, the excessive exploitation of natural resources has led to increased energy costs, adverse environmental impacts, and intensified climate change.

The environmental consequences of energy consumption have now been widely acknowledged, and priority must be given to sustainable energy use through rational consumption planning and the systematic implementation of energy efficiency measures across all sectors of the system. Owing to both global and local factors, the prices of energy and energy carriers are expected to continue increasing in the foreseeable future, directly influencing the cost of living and business operations.

Energy efficiency represents the aggregate of planned and implemented measures aimed at achieving the required level of service or production with the minimum possible energy input. In other words, it refers to performing the same function or operation while consuming less energy, without compromising comfort or productivity. Among all sectors of energy consumption, the building sector remains the dominant consumer.

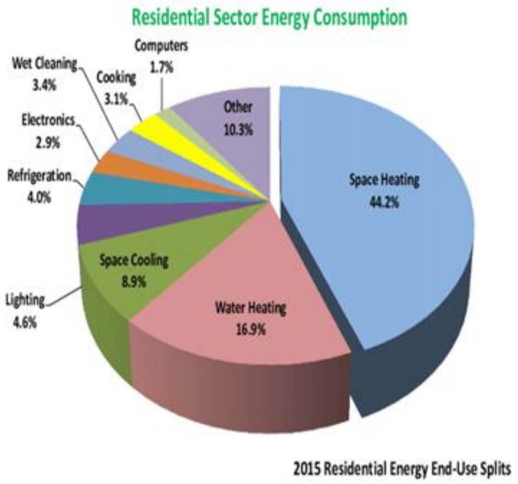

Figure 1. Percentage display of energy consumption

Energy efficiency and sustainable construction, along with the application of renewable energy sources, have become key

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priorities in the fields of construction and energy management within the European Union and worldwide.

Energy-sustainable construction aims to reduce energy demand in the building sector without compromising the quality of construction or living standards. Sustainable construction minimizes the environmental impact of building activities and is based on the use of environmentally friendly construction materials, high energy performance of buildings, and the management of waste throughout the entire life cycle of a building. Buildings represent the largest individual energy consumers and, due to their long service life, cannot be overlooked in the pursuit of sustainable energy goals.

Certain construction materials, such as concrete, require a significant amount of energy during their production. Cement, for instance, undergoes three stages of firing in the production process, which demands large quantities of energy and results in substantial CO_2 emissions. The same applies to insulation materials such as mineral wool and glass wool, as well as to synthetic materials like expanded polystyrene. These materials not only require high energy input for production but also pose environmental risks, as their recycling and disposal demand additional energy. Furthermore, transportation energy costs must be taken into account, since these materials are typically bulky and heavy. The energy consumed during the operational phase of a building over a 25-year period is estimated to be approximately ten times greater than the energy required for the production of construction materials (Motik, 2009).

The overall energy balance of a building should be minimized. Thermal energy gains should adequately compensate for heat losses in order to maintain comfortable indoor conditions.

The total annual delivered energy is calculated according to the following formula:
$E_{del} = Q_H + Q_C + Q_{ve} + E_I + Q_{aux}$ $[kWh/a]$ (Regulation on the Energy Efficiency of Buildings of the Republic of Serbia)
Where: Q_H-energy for space heating and domestic hot water preparation, Q_C- energy for space cooling, Q_{ve}- energy for ventilation and air-conditioning systems, Q_l- energy for lighting, Q_{aux}- energy for the operation of auxiliary systems.

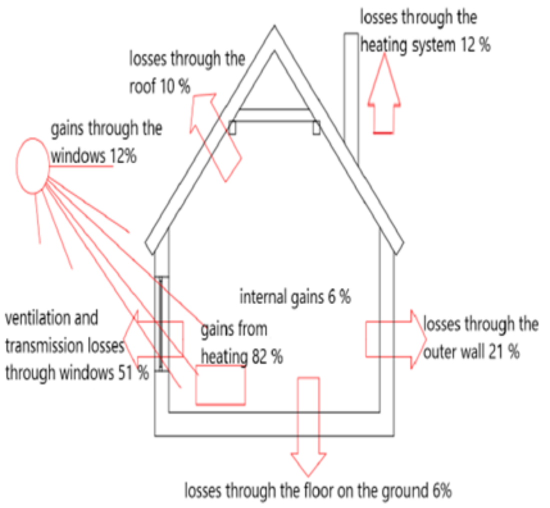

Figure 2. Heat losses and gains in the facility during the heating season *[15];*

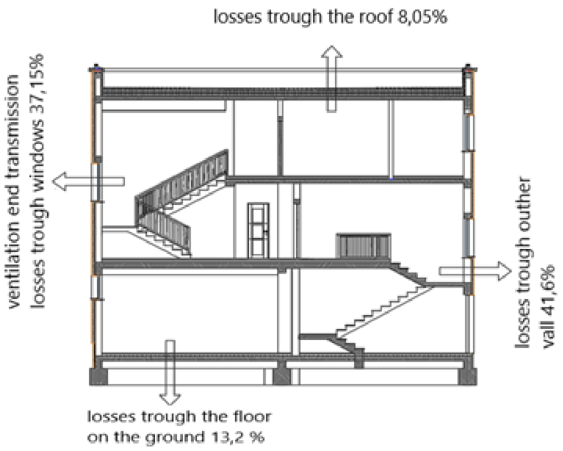

Figure 3. Heat loss distribution of the analyzed building

1. Thermally Efficient Building Materials

The building sector accounts for approximately 40% of total energy consumption. This figure not only includes the energy required for heating and cooling but also the energy embodied in the materials from which houses and buildings are constructed. Energy-efficient construction significantly contributes to reducing overall energy consumption. The production of most modern construction materials requires large amounts of energy, while some also cause harmful and toxic emissions that pollute the environment.

Investors rarely comply with quality regulations, and new buildings are often not insulated in accordance with even the existing, already insufficient, energy standards. Consequently, such buildings consume excessive amounts of energy—mostly derived from fossil fuels—for heating, cooling, and maintenance (Šišak, 2009).

The role of thermal insulation materials is to reduce heat losses and energy costs while protecting the building's load-bearing structure from atmospheric influences. Through the appropriate selection and proper implementation of thermal insulation materials, it is possible to save significantly more energy during a building's operation than the energy required for the production of those materials. Comprehensive knowledge of construction materials is essential to achieve optimal energy performance in building design. Today's market offers a wide range of products suitable for low-energy and passive buildings.

High-quality construction and effective insulation of a building and its individual components represent the most sustainable means of preventing heat losses and improving energy efficiency. According to the principles of passive building design, all elements of the building envelope should have a thermal transmittance coefficient (U-value) lower than 0.15 W/m²K, meaning that no more than 0.15 W of heating energy should be lost per square meter of floor area for every degree of temperature difference.

Thermal insulation materials can generally be divided into two categories: conventional and ecological.

Conventional materials include glass wool, rock wool, and expanded polystyrene (EPS), which are of inorganic origin. Ecological materials, on the other hand, are of organic origin and have little or no adverse environmental impact throughout their life cycle—from production to application. These include straw, coconut fibers, cotton, cork, sheep wool, cellulose, wood, clay, perlite, and hemp fibers.

The growing demand for thermal insulation materials of increasing thickness has driven the development of new technologies, resulting in the emergence of advanced thin insulation systems, such as transparent thermal insulation and vacuum insulation panels (VIPs).

Transparent insulation allows the penetration and transfer of solar energy into the building while simultaneously preventing heat losses—functioning similarly to conventional insulation. Vacuum insulation, manufactured in modular panel form, provides exceptional thermal resistance, enabling the same level of insulation performance at significantly reduced thicknesses compared to traditional materials. However, due to its high cost, vacuum insulation is currently used primarily in the retrofitting of historic and culturally valuable buildings, where the installation of thicker insulation layers is not feasible.

2. Vacuum Insulation Panels (VIP), OPTIM-R

Vacuum insulation panels (VIPs) represent a high-performance thermal insulation component that has been recently introduced into building technology. Their exceptionally high thermal resistance makes them suitable for applications where a thin yet highly energy-efficient building envelope is required. They are commonly used as insulation materials on flat roofs and terraces, in building retrofits where there is insufficient space for external insulation, as well as in new constructions as part of the external insulation system.

A vacuum insulation panel can be described as a porous material from which the air has been evacuated and which is enclosed within a multi-layer protective envelope. Due to the extremely low thermal conductivity of the vacuumized core and the relatively high thermal conductivity of the aluminum layers in the surrounding barrier film, these panels constitute a distinctly non-homogeneous material.

The principal components of a VIP include the **core,** the **core envelope (or vacuum bag),** and the **barrier film**.

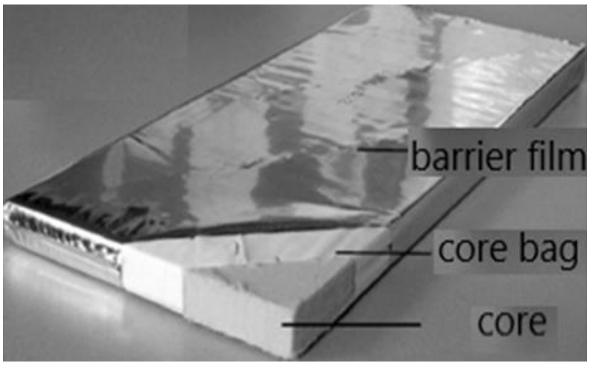

Figure 4. Vacuum Insulation Panel (VIP)

The envelope of a vacuum insulation panel can be made either of a thin metallic coating or of a multi-layer barrier composed of metallized polymer films that protect the panel from external influences.

The core material must have a porous structure with pores of minimal size, as heat transfer through the material must be suppressed. Such cores are typically made of open-pore foams, powders, or certain types of fibrous materials. The geometry of the core must be designed to ensure minimal contact points within the structure, thereby reducing conductive heat transfer even under significant mechanical loads [14].

Vacuum insulation panels exhibit up to eight times higher thermal insulation performance compared to conventional insulating materials. Consequently, 40 cm of traditional insulation can be effectively replaced with only 5–10 cm of VIP insulation, providing equivalent thermal resistance.

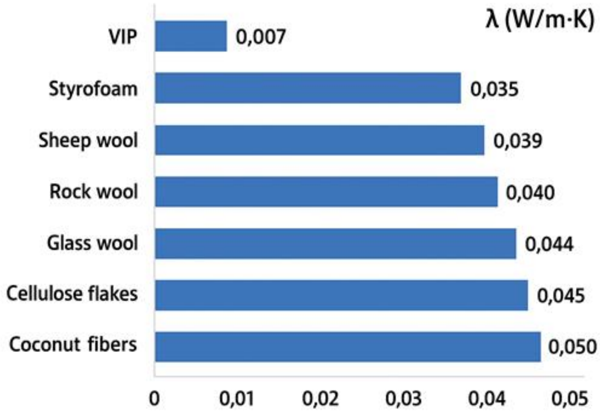

Figure 5. Comparison of Thermal Conductivity Coefficients for Various Insulation Materials

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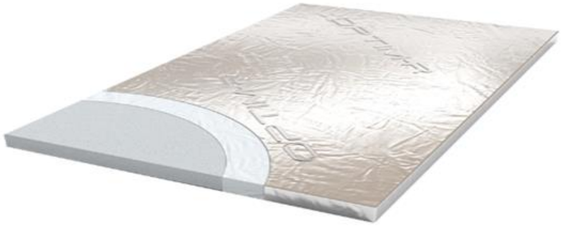
Vacuum Insulation Panels (VIPs) are highly suitable for use in confined or space-limited areas due to their exceptionally low thermal conductivity coefficient. Interest in VIP technology emerged in the late 20th century, when refrigerator and freezer manufacturers sought alternatives to CFC-oxidized foams. As vacuum technology was introduced in refrigerators, freezers, and transport packaging, it became evident that the same principle could be effectively applied to energy-saving purposes in the construction industry.

However, VIPs also have certain disadvantages, such as the formation of thermal bridges at the joints between panels and the gradual loss of insulation performance over time. For this reason, extensive research has been focused on prolonging the service life of VIPs. Larger panels generally exhibit longer expected lifetimes compared to smaller ones. The influence of panel size is related to the ratio between the panel volume and the width of the sealed edge, as well as between the panel volume and the barrier surface area. The edges of the sealed barrier films represent zones of increased gas permeation.

The main factors affecting the service life of vacuum insulation panels include panel size, manufacturing quality, component selection, operating conditions, and handling. From a thermal perspective, VIPs are strictly non-homogeneous materials, due to the extremely low thermal conductivity of their vacuum-packed core—ranging from 0.004 to 0.008 W/(m·K) (depending on aging effects)—and the very high thermal conductivity of the aluminum layers (approximately 230 W/(m·K)**)** in their boundary envelope.

The material used in this study is OPTIM-R**,** a product developed by Kingspan**,** which also belongs to the group of vacuum insulation materials. OPTIM-R consists of a rigid vacuum insulation board with a microporous core enclosed in a thin, gas-tight envelope. The OPTIM-R panels provide outstanding thermal performance and represent the thinnest high-quality insulation solution for use in limited spaces.



Slika 6. OPTIM-R [11]

OPTIM-R represents a vacuum insulation system with unique performance parameters.

This product is suitable for a wide range of applications, including:

- constructions with ventilated air cavities,
- thermal insulation of façades,
- thermal insulation of roof slabs,
- thermal insulation of pitched roofs,
- thermal insulation of floors,
- thermal insulation of frame structures,
- thermal insulation of agricultural buildings, and
- technical insulation applications.

Figure 7. Example of OPTIM-R application for wall insulation [11]

OPTIM-R provides the optimal performance of a rigid vacuum insulation panel (VIP), with a declared thermal conductivity of only 0.007 W/mK, delivering insulation performance up to five times greater than that of conventional insulating materials.

The core of the insulation material ensures superior thermal protection in both warm and cold climatic conditions. The insulation is applied to the exterior of the building**,** forming a thermal envelope that minimizes indoor temperature losses and provides protection from external temperature variations.

Its closed-cell structure prevents the penetration of moisture and air infiltration, ensuring long-term thermal reliability**.** The product maintains its insulating performance over time, as it does not age or degrade**.** Furthermore, hermetic sealing guarantees full protection against air leakage and atmospheric influences.

Figure 8. Example of using OPTIM-R for floor insulation [11]

3. Proračun i uporedna analiza toplotnih performansi

3.1. Metodologija i ulazni parametri

4. Calculation and Comparative Analysis of Thermal Performance

4.1. Methodology and Input Parameters

The calculation of the required heating energy for the newly designed building was carried out for two variants. **Variant I** employs *expanded polystyrene (EPS)* as the thermal insulation material, while **Variant II** utilizes *OPTIM-R vacuum insulation panels (VIP)*. All other construction layers (walls, floors, ceilings, and joinery) are identical in both variants. The calculation was performed in accordance with the recommendations of the *Regulation on the Energy Efficiency of Buildings of the Republic of Serbia* (Official Gazette of RS, No. 61/11) and the *ISO 6946* standard for determining the thermal transmittance coefficient.

The thermal transmittance coefficient (U-value) was determined according to the following expression:

$$U = \frac{1}{R_{si} + \sum \frac{d}{\lambda} + R_{se}},$$

where:

- d – thickness of the material layer (m),
- λ – thermal conductivity coefficient (W/m·K),
- R_{si} – internal surface thermal resistance (m²·K/W),
- Rse – external surface thermal resistance (m²·K/W).

able 1. Location Parameters and Climatic Data of the Building

Type of construction	New building
Location	Novi Sad, Srbia
Altitude	80 m
Year of construction	2021
Design outdoor temperature	-14.8 °C
Design indoor temperature	+20.0 °C

The most significant measure for improving the **energy efficiency of buildings** is the application of appropriate **thermal insulation materials**. In addition, important factors include the **building shape**, the presence of **thermal bridges**, and the **building shape factor**.

$$F_o = \frac{A}{V_e}\ [m^{-1}]$$

where:

- $\mathbf{F_o}$ – shape factor,
- **A** – usable floor area [m²],
- $\mathbf{V_e}$ – heated volume [m³].

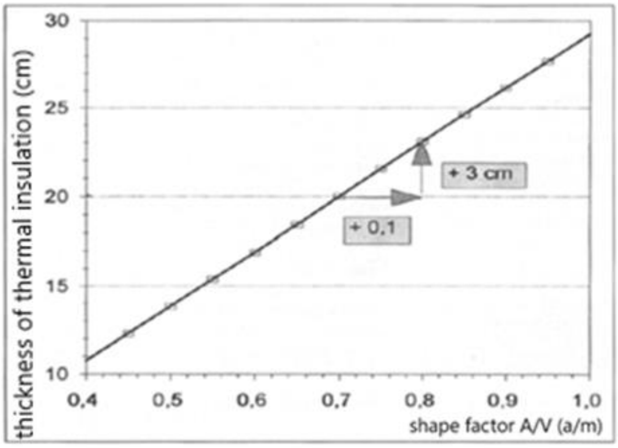


Figure 9. Relation between shape factor and insulation thickness

4.2. Variant I – Expanded Polystyrene (EPS) Insulation

For Variant I, *expanded polystyrene (EPS)* with a thickness of 10 cm was used as the thermal insulation layer. The obtained U-values indicate that EPS provides a satisfactory level of thermal protection with a typical insulation thickness used in residential buildings.

The tables and graphical representations show:

- material layers with their thermal conductivity coefficients (λ),
- calculated thermal resistances and U-values,
- diagrams of heat losses for individual building elements.

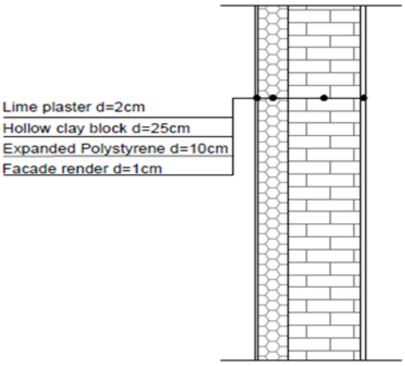


Figure 10. Cross-section of the wall – Variant I

Table 2. Calculation of the thermal transmittance coefficient through the wall

Description / Material	λ – Thermal conductivity (W/m K)	d- Thickness (m)	R – Thermal resistance (m^2 • K/W)	h_i – Internal heat transfer coefficient (W/m^2 •K)	U-thermal transmittance coefficient ($^W/_{m^2\,°C}$)
Exterior plaster	0,700	0,010	0,014	70,000	0,29
Expanded polystyrene (EPS) insulation	0,035	0,100	2,85	0,350	
Hollow clay block	0,610	0,250	0,410	2,440	
Lime-cement interior plaster	0,850	0,020	0,024	42,500	

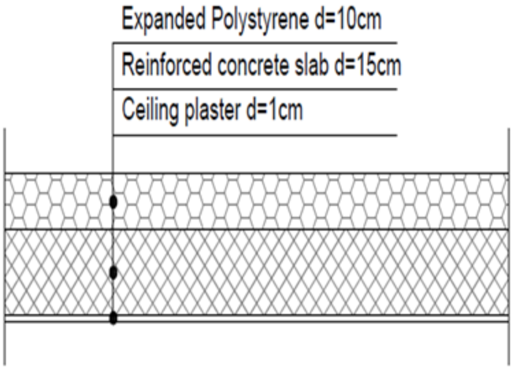


Figure 11. Cross-section of the intermediate floor structure above the second floor (attic slab)

Table 3. Calculation of the thermal transmittance (U-value) for the inter-story slab above the 2nd floor (attic slab)

Description / Material	λ – Thermal conductivity (W/m K)	d- Thickness (m)	R – Thermal resistance (m^2 •K /W)	h_i – Internal heat transfer coefficient (W/m^2 •K)	U-thermal transmittance coefficient ($^W/_{m^2\,°C}$)
Expanded polystyrene (EPS) insulation	0,035	0,12	3,429	0,292	0,27
Reinforced concrete slab (RC slab)	2,330	0,150	0,064	15,533	
Lime-cement plaster	0,850	0,010	0,012	85,000	

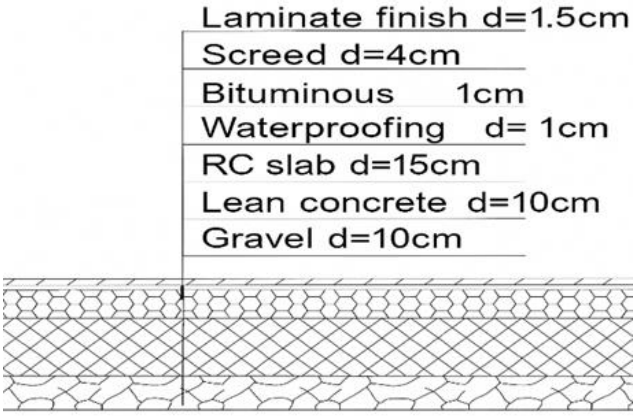


Figure 12. Cross-section of the ground floor slab

Table 4. U-value calculation - ground floor slab

Description / Material	λ – Thermal conductivity (W/mK)	d- Thickness (m)	R – Thermal resistance (m2•K/W)	h_i – Internal heat transfer coefficient (W/m2•K)	U- thermal transmittance coefficient $({}^{W}/_{m^2}$ °C
Laminate flooring	0,21	0,015	0,071	14,000	0,29
Cement screed	1,4	0,04	0,029	35,000	
Thermal insulation layer	0,035	0,12	3,429	0,292	
Waterproofing membrane	0,19	0,01	0,053	19,000	
RC slab	2,33	0,15	0,064	15,533	
Lean concrete layer	2,33	0,1	0,043	23,300	
Gravel base	0,81	0,1	0,123	8,100	

5.3 Variant II – Vacuum Insulation Panel (VIP) OPTIM-R

In the second variant, OPTIM-R vacuum insulation panels (VIP) with a thickness of 2–3 cm were applied. Due to their extremely low thermal conductivity coefficient, OPTIM-R panels provide equivalent or superior thermal performance compared to EPS, while significantly reducing the thickness of the insulation layer and increasing the usable floor area.

The tables and graphical representations show:

comparison of U-values for identical building elements,

- visual cross-sections of the wall and floor with OPTIM-R panels,
- **calculated transmission heat losses.**

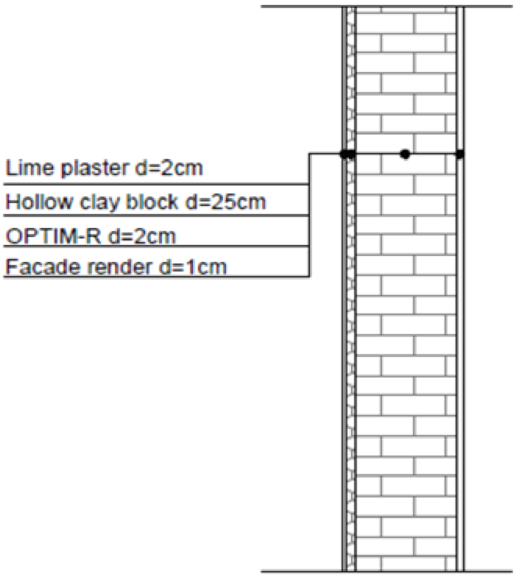


Figure 13. Cross-section of the wall with the new insulation material

Table 5. Calculation of the thermal transmittance (U-value) for the wall with the new insulation material

Description / Material	λ – Thermal conductivity (W/mK)	d- Thickness (m)	R – Thermal resistance (m^2•K/W)	h_i – Internal heat transfer coefficient (W/m^2•K)	U- thermal transmittance coefficient $({}^{W}/_{m^2}$ °C
OPTIM-R	0,007	0,02	2,857	0,350	0,29

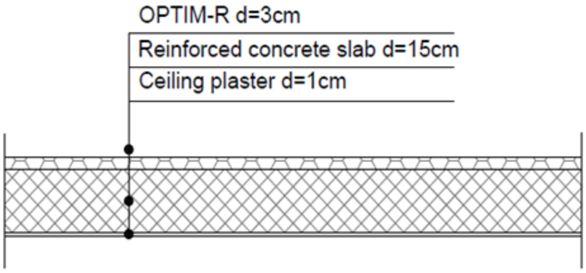


Figure 14. Cross-section of the slab above the second floor with the new insulation material

Tabela 6. Proračun koeficijenta toplote kroz ploču iznad II sprata sa novim izolacionim materijalom

Description / Material	λ – Thermal conductivity (W/mK)	d- Thickness (m)	R – Thermal resistance (m^2 •K /W)	h_i – Internal heat transfer coefficient (W/m2 •K)	U- thermal transmittance coefficient ($^W/_{m^2\ °C}$
OPTIM-R	0,007	0,03	4.286	0,235	0,22

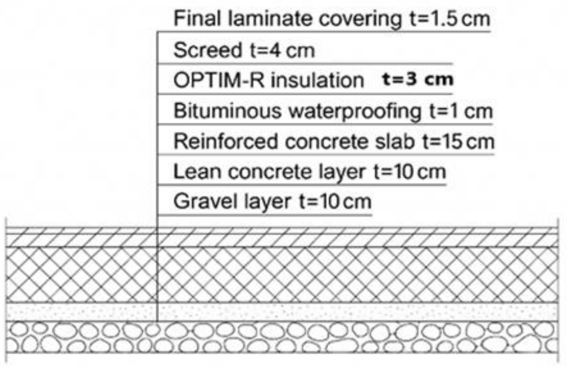


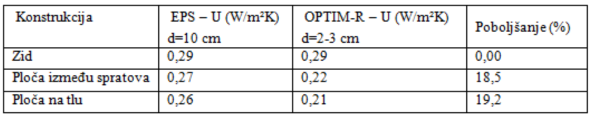
Figure 15. Cross-section of the floor slab with the new insulation material

Table 7. Calculation of the thermal transmittance (U-value) for the floor slab with the new insulation material

Description / Material	λ – Thermal conductivity (W/mK)	d- Thickness (m)	R – Thermal resistance (m^2 •K /W)	h_i – Internal heat transfer coefficient (W/m^2 •K)	U- thermal transmittance coefficient ($^W/_{m^2\ °C}$
Optim R	0,007	0,03	4.669	0,35	0,21

5.4 Uporedni rezultati i diskusija

Tabela 8. Uporedna analiza koeficijenata prolaza toplote (U-vrijednosti) za EPS i OPTIM-R izolaciju



Konstrukcija	EPS – U (W/m²K) d=10 cm	OPTIM-R – U (W/m²K) d=2-3 cm	Poboljšanje (%)
Zid	0,29	0,29	0,00
Ploča između spratova	0,27	0,22	18,5
Ploča na tlu	0,26	0,21	19,2

The comparative thermal analysis demonstrates that the application of OPTIM-R vacuum insulation panels (VIP) leads to a significant improvement in the thermal performance of building envelopes compared to traditional expanded polystyrene (EPS) insulation.

The key distinction between the two variants lies in the thickness of the insulation layer. While EPS requires approximately 10 cm, the OPTIM-R panels achieve the same or even superior performance with only 2–3 cm of thickness. This represents a reduction of over 70% in physical thickness, while simultaneously increasing thermal resistance and reducing transmission heat losses.

For the intermediate and ground floor slabs, the calculated U-values show a reduction of 18–20% in favor of the OPTIM-R panels, indicating lower heat transmission and consequently lower energy demand for heating. These results are particularly relevant for building renovations and energy retrofits, where available space is limited and the installation of thicker insulation layers is not feasible.

The use of OPTIM-R enables achieving three to five times thinner insulation layers without compromising thermal efficiency, offering multiple practical advantages such as increased usable space**,** reduced structural load**,** and simplified installation in confined or constrained areas.

Although the initial **cost** of the OPTIM-R system is higher than that of conventional materials, the long-term energy savings and the extended material lifespan contribute to its overall cost-effectiveness. Moreover, VIP panels retain stable thermal performance over time, as they are resistant to moisture and aging-related degradation.

Overall, the results confirm that the use of OPTIM-R vacuum insulation panels represents an advanced insulation technology, combining high energy efficiency with space-saving benefits, making it one of the most promising solutions in contemporary building thermal protection.

5. Conclusion

This study presented a comparative assessment of thermal performance between two insulation materials: the conventional expanded polystyrene (EPS) and the innovative vacuum insulation material OPTIM-R (VIP)**.**

The results demonstrate that the application of OPTIM-R panels can achieve equivalent or superior thermal protection with up to three to five times thinner insulation layers. With a thermal conductivity coefficient of only 0.007 W/mK**,** OPTIM-R provides approximately five times higher insulation efficiency compared to EPS. In addition to enhancing building energy efficiency, the use of this material contributes to environmental sustainability by reducing CO_2 emissions through lower operational energy demand. This aligns with global objectives for sustainable construction and energy-efficient design.
The OPTIM-R material also meets fire safety requirements, maintaining fire resistance for up to 30 minutes without flame spread across the façade, confirming its suitability for a wide range of building applications. Beyond façade insulation, it can be effectively used for floors, roofs, and intermediate slabs, making it applicable both in new constructions **and** renovation projects**.**

In conclusion, the application of OPTIM-R vacuum insulation panels represents a state-of-the-art solution that ensures high energy efficiency, spatial economy, and environmental responsibility. This makes OPTIM-R one of the most promising materials for the future of thermal insulation in the construction industry**.**

6. Literatura

1. Antonijević D., „Obnovljivi izvori energije, solarna energija“, Univerzitet Singidunum, Beograd. 2009.
2. Motik B., „Tehnologije za odrziv svijet: priručnik za odrzivo graditeljstvo o gospodarenju otpadnim vodama“, Blatuša, ZMAG, 2009.
3. Zakula B. 2015. Energetska učinkovitost i odrziva gradnja. Doktorska disertacija. Sveučilište Jurja Dobrile u Puli
4. Đonlagić M. 2017. Energetska efikasnost. Tuzla, Univerzitet u Tuzli
5. Pravilnik o Energetskoj Efikasnosti zgrada,Sl.glasnik. 2011. RS br 61/1
6. Grobovšek. 2007. Termoizolacijski materijali od prirodnih sirovina. Časopis građevinar
7. Šišak M. 2009. Mali priručnik za odrzivo zivljenje, Čakovec, KNEJA
8. Sotošek. 2014. Prevalencija oralnih simptoma kod radnika izlozenih aerosolima kamene vune. Zagreb
9. http://www.knaufinsulation.hr/kamena-vuna-i-kako-nastaje (15. septembar, 2022)
10. https://vipa-international.org/vips-used-in-buildings (18. septembar, 2022)
11. https://www.kingspan.com/rs/sr-latn-rs (19. septembar, 2022)
12. Jin-Hee Kim. 2016. Simulation performance of building wall with vacuum insulation panel. Science direct
13. Changhai Peng. 2020. Structure, Mechanism, and Application of Vacuum Insulation Panels in Chines Buildings. College of Engineering and Applied Science, University of Colorado Denver. USA
14. Mladen Stojiljković, Maja Todorović (2012) *Tematsko poglavlje 8 – Osnoveenergetskog balansiranja,* Inžinjerska komora Srbije, Beograd
15. Bukarica, V., Dović D., Borković Ž, Soldo V., Sučić B., Švaić S., Zanki V., Priručnik za energetske savjetnike (UNDP) u Hrvatskoj. Zagreb, (2008