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# Analysis of the Energy Efficiency of a Building Made of a Three-Layer Panel from Highly Porous Polystyrene Concrete

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Abstract: The study analyzes the thermal protection of a building located in Karaganda, Republic of Kazakhstan, using the ANSYS software, taking into account the region's cold climate. A newly developed energy-efficient three-layer panel made of highly porous polystyrene concrete was proposed, and its thermal characteristics were compared with those of traditional wall constructions made of solid and hollow ceramic bricks. As a result, the proposed new construction proved to be effective, with a thermal resistance value 8.8% and 5.6% higher than that of traditional constructions. Moreover, the analysis of specific characteristics and energy loads of the wall constructions demonstrated that the new three-layer panel made of highly porous polystyrene concrete is 2.5% more efficient than traditional solutions. Additionally, the proposed construction can reduce construction costs by up to 15% compared to conventional options. The findings of this study can be utilized by scientific and technical centers in the design or renovation of buildings.

## 1 INTRODUCTION

In the contemporary world, increasing attention is being paid to the issue of building and structure energy efficiency. Energy efficiency refers to the ability of buildings and structures to use energy more efficiently, thereby reducing energy consumption and harmful environmental emissions. In many countries, energy used for heating residential premises accounts for up to 40% of the energy consumption in the residential sector, representing the largest expenditure item (Kurt, 2010). Therefore, effective insulation of residential buildings plays a crucial role in reducing energy consumption in the residential sector (Demirbas, 2001; Bolatturk, 2006). Optimal wall and roof insulation can save over 70% of the energy required for heating (Hasan, 1999). For instance, in multi-apartment residential buildings, heat losses occur as follows: 20-30% through facade walls, 30-40% through airing systems, 12-25% through windows and entrance doors, 10-20% through the roof, and 3-6% through the basement (Tagybayev, Baidilla, Sapargaliyeva, Shakeshev, Baibolov, Duissenbekov, Utelbayeva, Kolesnikov, Izbassar, Kozlov, 2023; Zhangabay, Zhangabay, Utelbayeva, Tursunkululy, Sultanov, Kolesnikov, 2025; Tursunkululy, Ibraimova, Abdikerova, 2024; Cholewa, Balaras, Nižetić, Siuta-Olcha, 2020). This study places particular emphasis on exterior walls due to the diversity of structural solutions (Kudabayev, Mizamov, Zhangabay, Suleimenov, Kostikov, Vorontsova, Buganova, Umbitaliyev, Kalshabekova, Aldiyarov, 2022; Zhangabay, Kudabayev, Mizamov, Imanaliyev, Kolesnikov, Moldagaliyev, Merekeyeva, 2023; Zhangabay, Baidilla, Tagybayev, Suleimenov, Kurganbekov, Kambarov, Kolesnikov, Ibraimbayeva, Abshenov, Volokitina, Nsanbayev, Anarbayev, 2023; Tagybayev, Utelbayeva, Buganova, Tolganbayev,

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Tulesheva, Jumabayev, Kolesnikov, Kambarov, Imanaliyev, Kozlov, 2023; Zhangabay, Baidilla, Tagybayev, Sultan, 2023; Bonopera, Baidilla, Utelbayeva, Tursunkululy, 2023) and the use of innovative materials (Chepela, Tursunkululy, Zhangabay, Kolesnikov, 2024). Additionally, key criteria for achieving building energy efficiency include adopted strategies (Michalak, 2021; Nik, Mata, Kalagasidis, Scartezzini, 2016; Zhangabay, Abshenov, Bakhbergen, Zhakash, 2022; Tazhentayeva, Ahmed, 2024) and regulatory documentation. Collectively, addressing these issues leads to significant thermal energy savings. Various researchers have explored different approaches to achieving energy efficiency. For example, in (Qi, Utaberta, Lau, Yanfang, Xiyao, 2025), two types of green facades were applied to the facade systems to enhance building energy efficiency. The study (Kontoleon, Eumorfopoulou 2010) revealed that rooms with indirect green facades covered with Parthenocissus quinquefolia demonstrated the highest energy-saving level of 45.75%. In contrast, rooms with direct green facades covered with Humulus scandens achieved an energy-saving coefficient of only 6.43%. The article (Ibrahim, Imghoure, Tittelein, Belouaggadia, Chehade, Sebaibi, Lassue, Zalewski, 2025) provides a comprehensive review of recent studies on passive ventilated solar facades and their integration into building envelopes, focusing on relevant improvements in energy efficiency and the reduction of traditional heating and cooling methods (Tagybayev, Zhangabay, Suleimenov, Avramov, Uspenskyi, Umbitaliyev, 2023; Zhangabay, 2024; Zhangabay, 2024). The review (Gonçalves, Figueiredo, Almeida, 2024) examines the influence of climate and thermal inertia on these results. The analysis of adaptive dynamic facades demonstrated their high efficiency in enhancing overall performance (Zhangabay, Tursunkululy, Utelbayeva, Abdikerova, Sultanov, 2025; Zhangabay, Oner, Rakhimov, Tursunkululy, Abdikerova, 2025). In (Alpar, Berger, Mazuroski, Belarbi, 2024), a practical study is conducted on a house wall exposed to different climatic conditions throughout the year (Giyasov, Ibraimova, Tursunkululy, Kolesnikov, 2024). Optimal shapes of the outer wall boundary are determined, considering that the optimized facade uses the same amount of material as a standard flat facade. The results indicate a substantial improvement in energy efficiency compared to the reference flat wall.

Article (Ivanović-Šekularac, Čikić-Tovarović, Šekularac, 2016) presents the traditional impact of using wood as a cladding element in modern architecture, offering an analysis of the functional and design potential of wood as part of ventilated facade systems and its effect on energy efficiency. Special attention is given to an object subjected to various reconstruction methods and facade system modifications to meet energy-saving requirements. The authors in (Zhangabay, Bakhbergen, Aldiyarov, Tursunkululy, Kolesnikov, 2024) review recent advances in the development of thermal energy storage materials for building applications (Borodin, Zhangabay, 2019), focusing on low-rise buildings in the context of environmental climate parameters (Zhangabay, Giyasov, Ybray, Tursunkululy, Kolesnikov, 2024; Giyasov, Ybray, Tursunkululy, 2024; Stanevich, Bulyga, Vyshar, Girnis, Rakhimova, 2022).

The conducted literature review indicates that diverse innovative structural solutions and new energy-efficient materials are being implemented to achieve building energy efficiency. However, the review also identifies certain gaps in the comprehensive assessment of building energy efficiency considering exterior facade structures. In continuation of the work (Rakhimova, Zhangabay, Samoilova, Rakhimov, Kropachev, Stanevich, Karacasu, Ibraimova, 2024), the authors propose conducting an energy assessment to determine the building's energy efficiency class, based on a previously developed three-layer panel structure. It should be noted that improving the energy efficiency of existing buildings will lead to additional savings in maintenance costs (Ibraimova, Suleimenov Moldagaliyev Buganova, Jumabayev, Kolesnikov, Tursunkululy,2023; Zhangabay, Ibraimova, Bonopera, Suleimenov, Avramov, Chernobryvko, Utelbayeva, Uspenskiy, 2024; Zhangabay, Ibraimova, Ainabekov, Buganova, Moldagaliev, 2024; Zhangabay, Ibraimova, Tursunkululy, Buganova, Moldagaliev, Duissenbekov, 2024; Zhangabay, Ibraimova, Bonopera, Suleimenov, Avramov, Chernobryvko, Yessengali, 2024) and in the construction of energy sector facilities (Tursunkululy, Avramov, Chernobryvko, Suleimenov, Utelbayeva, 2022; Suleimenov, Abshenov, Utelbayeva, Imanaliyev, Mussayeva, Moldagaliyev, Yermakhanov, Raikhanova, 2022; Duissenbekov, Tokmuratov, Yerimbetov, Aldiyarov, 2020; Tursunkululy, Avramov, Chernobryvko, Kambarov, Abildabekov, Narikov, Azatkulov, 2023).

# 2 METHODS AND MATERIALS

## 2.1 Exterior Wall Enclosure Structures

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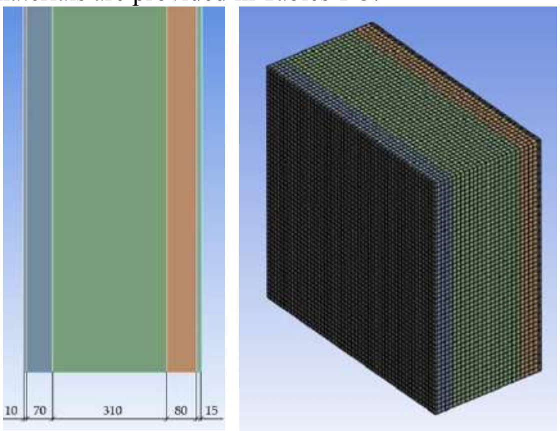
The analysis considered three types of exterior wall enclosures. A newly proposed design involved a three-layer panel made of highly porous polystyrene concrete, whose thermal performance indicators were compared with those of existing exterior wall enclosures made of solid and hollow ceramic bricks. The primary geometric characteristics of the wall structures are presented in Figures 1-3, while the thermal performance indicators of the construction materials are provided in Tables 1-3.




a b

Figure 1: Wall structure made of highly porous polystyrene concrete (Option 1): a. Geometric parameters of the wall structure; b. Finite element model containing 64,068 hexagonal finite elements with 297,431 nodes, where the average element quality of the model is 0.9735.

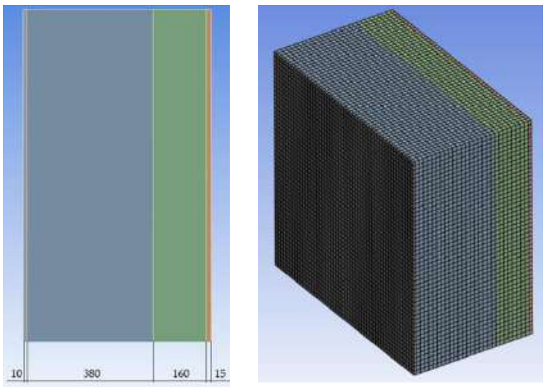



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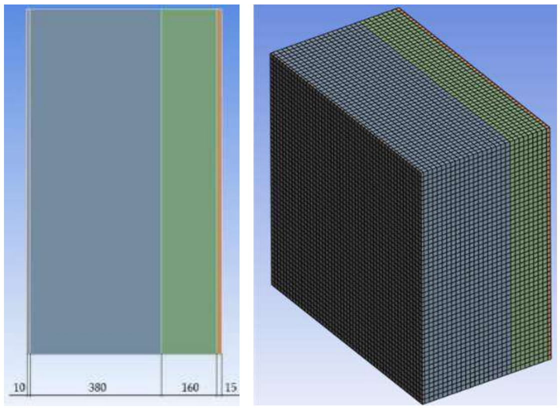
Figure 2: Wall structure made of solid ceramic brick (Option 2): a. Geometric parameters of the wall structure; b. Finite element model containing 72,500 hexagonal finite elements with 329,562 nodes, where the average element quality of the model is 0.9903.




a b

Figure 3. Wall structure made of hollow ceramic brick (Option 3): a. Geometric parameters of the wall structure; b. Finite element model containing 72,500 hexagonal finite elements with 329,562 nodes, where the average element quality of the model is 0.9903.

Table 1: Thermal Performance Indicators of Construction Materials for Figure 1.

| № | Layer Description | Thermal Conductivity for Operation Zone A, λ (W/(m·°C)) |
|---|---|---|
| | Cement-sand mortar, 10 mm | |
| | H | |
| | P | |
| | H | |
| | C | |

Table 2: Thermal Performance Indicators of Construction Materials for Figure 2.

| № | Layer Description | Thermal Conductivity for Operation Zone A, λ (W/(m·°C)) |
|---|---|---|
| | C | |
| | Solid ceramic brick, density 1800 kg/m³, 380 mm | |
| | Extruded polystyrene foam, density 35 kg/m³, 160 mm | |
| | C | |

Table 3: Thermal Performance Indicators of Construction Materials for Figure 3.

| № | Layer Description | Thermal Conductivity for Operation Zone A, λ (W/(m·°C)) |
|---|---|---|
| | C | |
| | Hollow ceramic brick, density 1000 kg/m³, 380 mm | |

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| | | |
|---|---|---|
| | Extruded polystyrene foam, density 35 kg/m³, 160 mm | |
| | C | |

## 2.2 Climatic and Internal Boundary Conditions of the Region

The study region is based on the climatic parameters of Karaganda, Republic of Kazakhstan. The main climate parameters are presented in Table 4.

Table 4: Climate Parameters of Karaganda.

| № | Indicators | Values |
|---|---|---|
| 1 | Indoor humidity mode | Normal |
| 2 | Humidity zone | Dry |
| 4 | Operating condition of enclosing structures | A |
| 3 | Average temperature of the coldest 5-day period with 0.92 reliability | –28.9 °C |
| 4 | Average annual humidity | 65% |
| 5 | Maximum of average wind speeds by compass points in January | 6.6 m/s |
| 6 | Heating season duration | 207 days |
| 7 | Indoor temperature in winter | 20°C |
| 8 | Indoor humidity | 55% |
| 9 | Required thermal resistance | 3.2 W/m²·°C |

## 2.3 Methodology for Evaluating the Thermal Protection of a Residential Building with Considered Wall Structures

The residential building subject to modernization is located in Karaganda, Republic of Kazakhstan, and its geometric parameters are presented in Table 5.

Table 5: Building Geometric Characteristics.

| Indicator | Standard Value | Actual Value |
|---|---|---|
| Total floor area (*A*), m² | - | 210.0 |
| Design area (public buildings) ($A_1$), m² | - | - |
| Heated volume (*V*), m³ | - | 570 |
| Façade glazing ratio (*f*) | ≤0.18 | 0.10 |
| Building compactness index ($K_1$) | 0.9 | 0.94 |
| Total area of external enclosing structures, including ($A_0$), m²: | - | 536.8 |
| 1) Walls (by type of construction), $A_2$ | - | 264.0 |
| 2) Windows and balcony doors, $A_3$ | - | 28.8 |
| 3) Entrance doors and gates (separately), $A_4$ | - | 4 |
| 4) Attic floors, $A_5$ | - | 120.0 |
| 5) Floors above technical subfloors or unheated basements, $A_6$ | - | 120.0 |

In Table 6, the methodology for assessing building thermal protection is presented.

Table 6: Methodology for Calculating Building Thermal Protection.

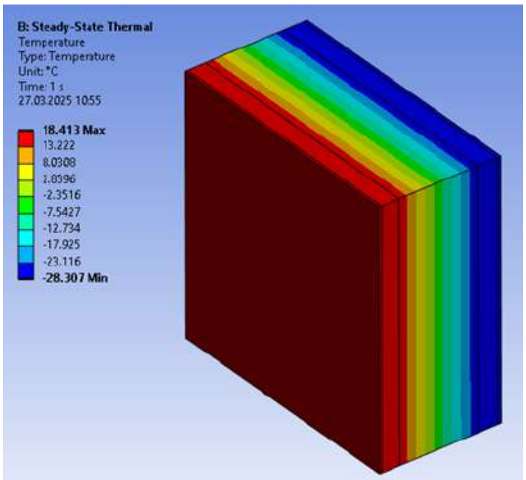
| | | |
|---|---|---|
| Determination of Heat Demand Days (HDD) | $HDD = (t_2 - t_3)z_1$ | $t_2$- Indoor air temperature, °C; $t_3$- Average outdoor temperature during the thermal heating phase, °C; $z_1$- Duration of the thermal heating phase, days/year. |
| Thermal values of materials, geometric and climatic values | The indicated values for analysis are presented in Tables 1-5. | |
| Thermal performance indicators. Determination of the indicator of the reduced thermal resistance of walls. | Thermal resistance of walls was determined in accordance with [24, 35, 45] using the ANSYS software. | |
| Auxiliary indicators. Overall heat transfer coefficient of the building. | $K_1 = \frac{L}{A_1^{sum}} \sum_i \left( n_{t,i} \frac{A_{f,j}}{R_{o,j}^1} \right)$ | $L$- Amount of supply air entering the building through unorganized inflow or regulated value for mechanical airing, m³/h; $A_1^{sum}$- Sum of areas (by internal measurement of all external enclosing structures of the heated building shell), m²; $n_{t,i}$ - Coefficient accounting for the difference between the internal or external temperature at the structure and those adopted in the HDD calculation; $A_{f,j}$ - Area of the corresponding fragment of the building's thermal protection shell, m²; $R_{o,j}^1$- Reduced thermal resistance of the i-th fragment of the building's thermal protection shell, m²·°C/W. |

| | | |
|---|---|---|
| Specific characteristics. Specific thermal protection characteristic of the building. | $k_1 = \frac{L}{V}\sum_i \left(n_{t,i}\frac{A_{f,i}}{R^1_{o,i}}\right) = k_1 \cdot k_2$ | $V$ – Heated volume, m³; $k_1$- Specific thermal protection characteristic of the building, W/(m³·°C); $k_2$- Specific characteristic of household heat emissions, W/(m³·°C). |
| Coefficients | The standard values are presented in Table 9. | |
| Comprehensive indicators | $q_1^p = k_1 + k_a - \beta_1(k_2 + k_{rad})$ | $k_a$- Specific airing characteristic of the building, W/(m³·°C); $\beta_1$- Air volume reduction factor in the building, accounting for the presence of internal enclosing structures; $K_{rad}$- Specific characteristic of heat gains from solar radiation, W/(m³·°C). |
| Energy Loads of the Building | $q = 0.24 \cdot HDD \cdot q_1^p \cdot h$ <br> $Q_1^y = 0.024 \cdot HDD \cdot V_1 q_1^p$ <br> $Q_2^y = 0.024 \cdot HDD \cdot V_1(k_1 + k_a)$ | |

# 3 RESULTS AND DISCUSSIONS

## 3.1 Finite Element Analysis of Temperature Fields in ANSYS

Figures 4-6 present the simulation results of temperature fields in exterior wall structures using ANSYS, in accordance with the methodology described in Section 2.

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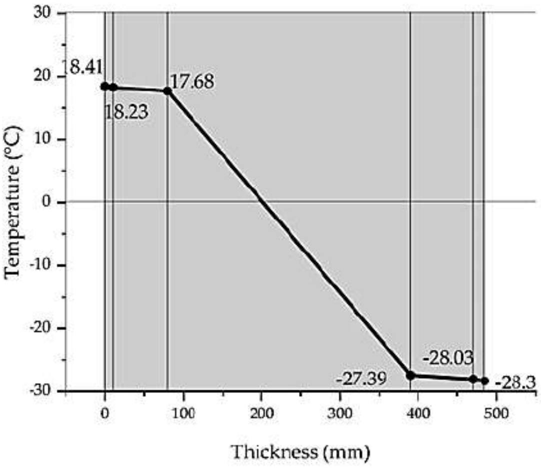
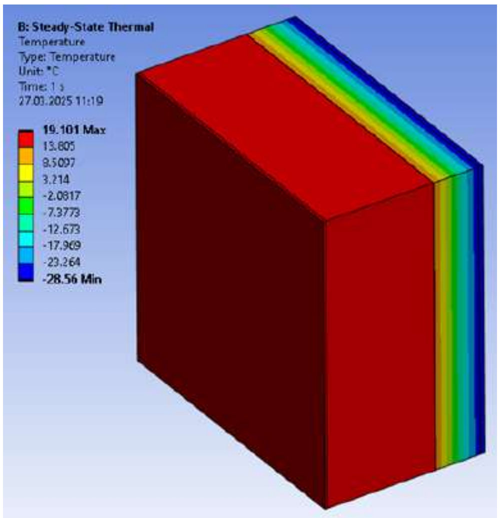



b

Figure 4: Temperature field in the wall enclosure according to Figure 1: a. Temperature field model in ANSYS; b. Temperature distribution diagram of the enclosure across layers.



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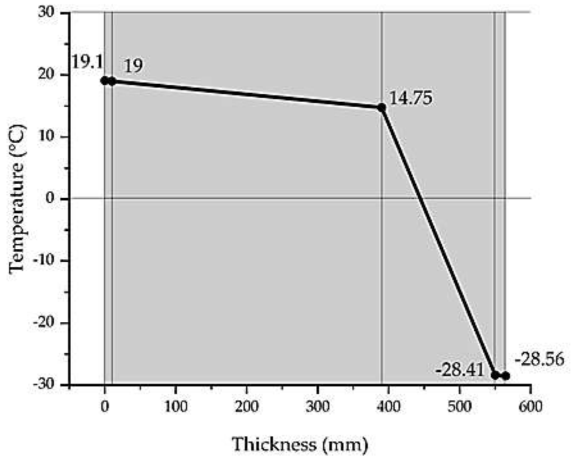
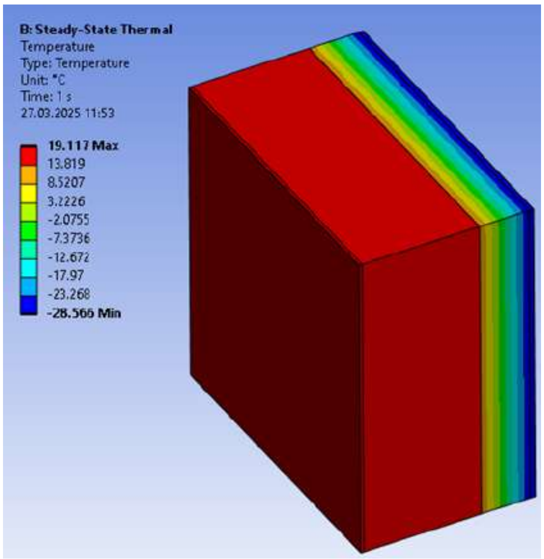
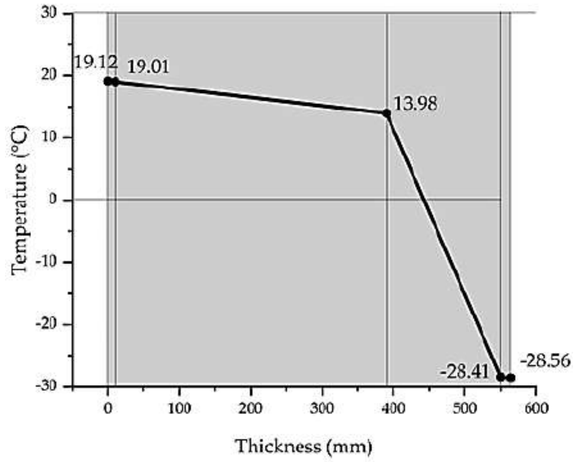



b

Figure 5: Temperature field in the wall enclosure according to Figure 2: a. Temperature field model in ANSYS; b. Temperature distribution diagram of the enclosure across layers.




a




b

Figure 6: Temperature field in the wall enclosure according to Figure 3: a. Temperature field model in ANSYS; b. Temperature distribution diagram of the enclosure across layers.

The result of the thermal resistance analysis of the studied exterior wall structures, conducted in accordance with the calculation method described in Section 2, is presented in Figure 7.

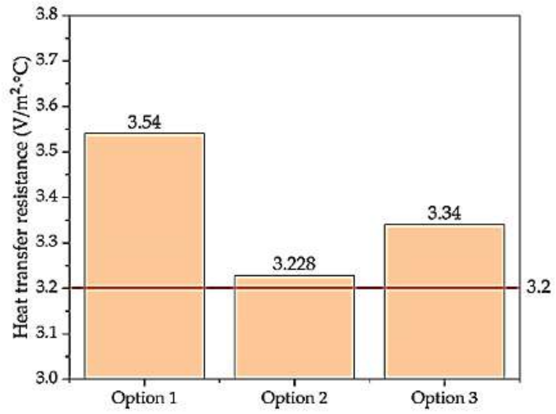



Figure 7: Thermal Resistance Values of the Considered Wall Structures

The analysis of temperature field values and thermal resistance of exterior wall structures demonstrates that all constructions meet the required thermal resistance value of 3.2 W/m²·°C. However, the newly proposed energy-efficient wall structure made of highly porous polystyrene concrete (Figure 1) significantly outperforms traditional structures made of solid ceramic brick (Figure 2) and hollow ceramic brick (Figure 3), showing an efficiency improvement of 8.8% and 5.6%, respectively.

## 3.2 Analysis of Building Thermal Protection Considering the Studied Exterior Wall Structures

An assessment of the studied facade structures was carried out based on the calculation methodology presented in Section 2. Table 7 presents the obtained and accepted values of the thermal resistance indicator for exterior wall enclosures, depending on the structure type.

Table 7: Values of the Reduced Thermal Resistance of Exterior Enclosures Depending on the Type of Enclosure.

| Type Exterior Enclosure | Standard Value, $m^2\cdot°C/W$ | Calculated Value, $m^2\cdot°C/W$ (Option 1) | Calculated Value, $m^2\cdot°C/W$ (Option 2) | Calculated Value, $m^2\cdot°C/W$ (Option 3) | Note |
|---|---|---|---|---|---|
| Exterior walls | . | . | . | . | Accepted according to Section 3.1 |
| Windows and balcony doors | . | . | . | . | Accepted conditionally |
| Entrance doors and gates (separately) | . | . | . | . | Accepted conditionally |
| Attic floors | . | . | . | . | Accepted conditionally |
| Floors above technical subfloors or unheated basements | . | . | . | . | Accepted conditionally |

Figure 8 presents auxiliary values in the form of the overall heat transfer coefficient of the building, calculated in accordance with the methodology presented in Section 2.

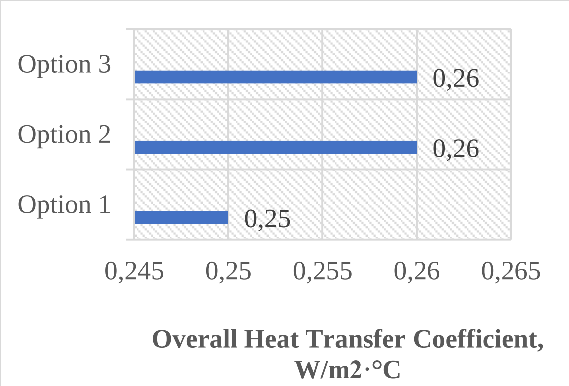



Figure 8: Value of the Overall Heat Transfer Coefficient of the Building

Table 8 presents the results of the analysis of the building's specific characteristics, calculated according to the calculation methodology presented in Section 2.

Table 8: Specific Characteristics of the Building.

| Indicator | Standard Value of the Indicator | Calculated Design Value of the Indicator (Figure 1a) | Calculated Design Value of the Indicator (Figure 1b) | Calculated Design Value of the Indicator (Figure 1c) | Note |
|---|---|---|---|---|---|
| Specific thermal protection characteristic of the building, $k_{total}$, $W/(m^3\cdot°C)$ | . | | . | . | Accepted according to Section 2.3 |
| Specific airing characteristic of the building, $k_{airing}$, $W/(m^3\cdot°C)$ | | | | | Accepted conditionally |
| Specific characteristic of household heat emissions, $k_{household}$, $W/(m^3\cdot°C)$ | | | | | Accepted conditionally |
| Specific characteristic of heat gains from solar radiation, | | | | | Accepted conditionally |

| $k_{radiation}$, W/(m$^3$·°C) | | | | | |
|---|---|---|---|---|---|

Table 9 presents the necessary adopted coefficients for determining the comprehensive energy efficiency indicators and the building's energy loads.

Table 9: Coefficient Values for Determining Comprehensive Energy Efficiency Indicators and Building Energy Loads.

| Indicator | Standard Value of the Indicator |
|---|---|
| Heating system self-regulation efficiency coefficient, ζ | . |
| Coefficient accounting for the reduction in heat consumption of residential buildings with individual heat metering for heating, ξ | . |
| Recuperator efficiency coefficient, $k_{eff}$ | |
| Coefficient accounting for the reduction in the use of heat gains during periods of excess over heat losses, *ν* | . |
| Coefficient accounting for additional heat losses from the heating system, $\beta_h$ | . |

Figure 9 presents the results of calculating the comprehensive energy efficiency indicator of the building in the form of the specific characteristic of heat energy consumption for heating and airing during the thermal heating phase for different exterior wall enclosures.

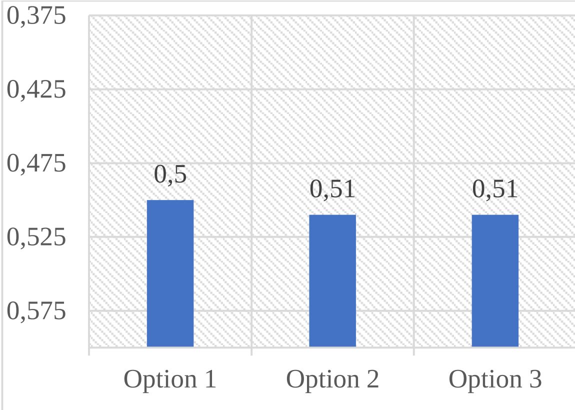



Figure 9: Values of the Comprehensive Energy Efficiency Indicators of the Building.

Figure 10 presents the results of the energy load calculations, including the specific heat energy consumption and the heat energy consumption for heating and airing during the thermal heating phase, as well as the building's total heat losses during the thermal heating phase, broken down by types of external enclosures.

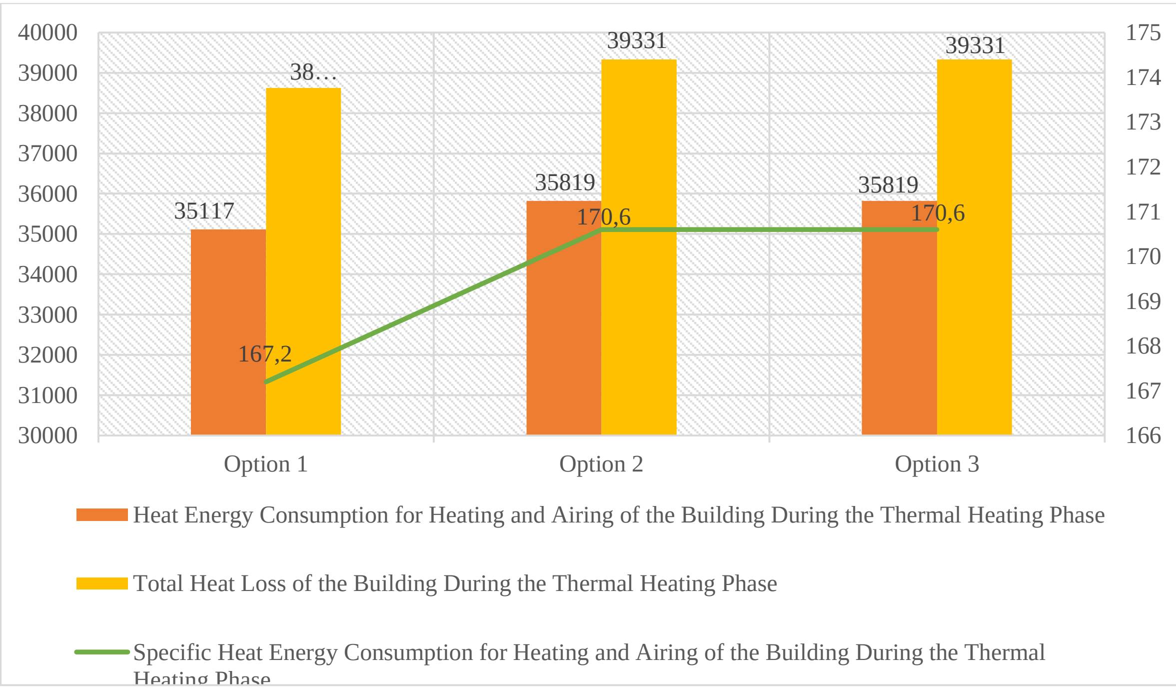



Figure 10: Energy Load Values of the Building.

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The analysis established that the effectiveness of the proposed new design was also demonstrated by the results of the study on the building's thermal protection, where the specific characteristics and energy loads of the building showed a 2.5% efficiency advantage compared to the other examined structures.

## 4 CONCLUSIONS

The study of the thermophysical parameters of the proposed new energy-efficient three-layer panel made of highly porous polystyrene concrete, compared to traditional solid and hollow brick structures using the ANSYS software package, established that the thermal resistance of the proposed new design is significantly higher than that of existing structures, with an efficiency increase of 8.8% and 5.6%, respectively. Similar results confirming the effectiveness of the proposed new design were demonstrated by the building's thermal protection analysis, where specific characteristics and energy loads of the building showed a 2.5% efficiency advantage compared to other examined structures. Additionally, the cost savings in construction using the proposed new design, compared to traditional structures, reached up to 15%. The findings of this study demonstrate that the use of a three-layer panel made of highly porous polystyrene concrete for exterior wall enclosures significantly improves the thermal performance of buildings. It was established that the application of such wall structures can lead to a significant increase in the overall energy efficiency rating of the building.

## REFERENCES


Kurt, H., 2010. The usage of air gap in the composite wall for energy saving and air pollution. Environmental Progress & Sustainable Energy. 30(3). P. 450–458.

Demirbas, A., 2001. Energy balance, energy sources, energy policy, future developments and energy investments in Turkey. Energy Conversion Management. 42. P. 1239–1258.

Bolatturk, A., 2006. Determination of optimum insulation thickness for building walls with respect to various fuels and climate zones in Turkey. Applied Thermal Engineering. 26. P. 1301–1309.

Hasan, A., 1999. Optimizing insulation thickness for buildings using life cycle cost. Applied Energy. 63. P. 115–124.

DOE: 2011 Building energy data book. Energy efficiency and renewable energy. – US, Department of Energy, 2011

Zhangabay, N., Zhangabay, A., Utelbayeva, A., Tursunkuluy, T., Sultanov, M., Kolesnikov, A., 2025. Energy-Efficient Outdoor Fencing with Air Layers: A Review of the Effect of Solar Radiation on the Exterior Fencing of Buildings Made of Composite Material. J. Compos. Sci. 9(1), 9.

Tursunkululy, T., Ibraimova U., Abdikerova, U., 2024. Energy-Efficient Adaptive Dynamic Building Facades: A Review of Their Energy Efficiency and Operating Loads. Appl. Sci. 14(23), 10979.

Chojewa, T., Balaras, C. A., Nižetić, S., Siuta-Olcha, A., 2020. On calculated and actual energy savings from thermal building renovations – Long term field

Kudabayev, R., Mizamov, N., Zhangabay, N., Suleimenov, U., Kostikov, A., Vorontsova, A., Buganova, S., Umbitaliyev, A., Kalshabekova, E., Aldiyarov, Z., 2022. Construction of a model for an enclosing structure with a heat-accumulating material with phase transition taking into account the process of solar energy accumulation. East. Eur. J. Enterp. Technol. 6, 26–37.

Zhangabay, N., Kudabayev, R.A., Mizamov, N., Imanaliyev, K., Kolesnikov, A., Moldagaliyev, A., Merekeyeva, A., 2023. Study of the model of the phase transition envelope taking into account the process of thermal storage under natural draft and by air injection. Case Stud. Constr. Mater. 18, e02050.

Zhangabay, N., Baidilla, I., Tagybayev, A., Suleimenov, U., Kurganbekov, Z., Kambarov, M., Kolesnikov, A., Ibraimbayeva, G., Abshenov, K., Volokitina, I., Nsanbayev, B., Anarbayev, Y., 2023. Thermophysical indicators of elaborated sandwich cladding constructions with heat-reflective coverings and air gaps. Case Stud. Constr. Mater. 18, e02161.

Tagybayev, A., Utelbayeva, A., Buganova, S., Tolganbayev, A., Tulesheva, G., Jumabayev, A., Kolesnikov, A., Kambarov, M., Imanaliyev, K., Kozlov, P., 2023. Analysis of the influence of thermal insulation material on the thermal resistance of new facade structures with horizontal air channels. Case Studies in Construction Materials. 18, e02026.

Zhangabay, N., Baidilla, I., Tagybayev, A., Sultan, B., 2023 Analysis of Thermal Resistance of Developed Energy-Saving External Enclosing Structures with Air Gaps and Horizontal Channels. Buildings. 13. 356.

Bonopera, M., Baidilla, I., Utelbayeva, A., Tursunkululy, T., 2023. Research of Heat Tolerance and Moisture Conditions of New Worked-Out Face Structures with Complete Gap Spacings. Buildings. 13(11). 2853.

Chepela, D., Tursunkululy, T., Zhangabay, A., Kolesnikov, A., 2024. Analysis of the effect of porosity on thermal conductivity with consideration of the internal structure

DOI: 10.63550/ICEIP.2025.56.67.028

of arbolite. Construction Materials and Products. 7 (3). 4.

Matic, D., Calzada, J. R., Eric, M., & Babin, M. Economically feasible energy refurbishment of p r [illegible]

Michalak, P., 2021. Selected Aspects of Indoor Climate in a Passive Office Building with a Thermally Activated Building System: A Case Study from Poland. Energies, 14(4), 860. [illegible]

Ringquist, B., & Schwab, S. (2017). [illegible] Energetic refurbishment – a global approach for the [illegible]

Nik[illegible] V. M., Mata, E., Kalagasidis, A. S., Scartezzini, J. L., 2016. Effective and robust energy retrofitting measures for future climatic conditions – Reduced heating demand of Swedish households. Energy and Buildings.

Zhangabay, N., Abshenov, K., Bakhbergen, S., Zhakash, A., 2022. Moldagaliyev, A. Evaluating the Effectiveness of Energy-Saving Retrofit Strategies for Residential Buildings. Int. Rev. Civ. Eng. 13, 118-126.

Tazhentayeva, E., Ahmed, A., 2024. A Renovation Framework for Energy Efficient Dilapidated Building Retrofitting in Kazakhstan. Chemical Engineering Transactions. 113:613-618.

EN 13788 Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods. 2001. https://cdn.standards.iteh.ai/samples/22203/9af8a8265 9944443b0873c17f99960e7/ISO-13788-2001.pdf (accessed on 21 J March 2025).

EN ISO 6946 Building components and building elements. 2017. https://www.en-standard.eu/iso-6946-2017-building-components-and-building-elements-thermal-resistance-and-thermal-transmittance-calculation-methods/ (accessed on 21 March 2025).

Code of Rules of the Republic of Kazakhstan 2.04-107-2022. Building Heat Engineering: State Standards in the Field of Architecture, Urban Planning and Construction. Code of Rules of the Republic of Kazakhstan. – JSC "KazNIISA", LLP "Astana Stroy-Consulting", 2013. Approved and Enacted on 1 July 2015. 80. Available online: https://online.zakon.kz/Document/?doc_id=39838250 (accessed on 20 March 2025).

Recommendations on the design of hinged facade systems with ventilated air gap for new construction and reconstruction of buildings. – Moskomarchitecture: Moscow. 2002, 159. https://files.stroyinf.ru/Data1/9/9931/ (accessed on 20 March 2025).

Code of Rules of the Republic of Kazakhstan 2.04-106-2012. Designing of thermal protection of buildings: State Standards in the Field of Architecture, Urban Planning and Construction. Code of Rules of the Republic of Kazakhstan. – JSC "KazNIISA", LLP "Astana Stroy-Consulting", 2013. Approved and Enacted on 1 July 2015. 153. Available online: https://online.zakon.kz/Document/?doc_id=35957424 (accessed on 20 March 2025).

Qi, S., Utaberta, N., Lau, A., Yanfang, X., Xiyao, H., 2025. Effects of green façade retrofitting on thermal performance and energy efficiency of existing buildings in northern China: An experimental study. Energy and Buildings. 335, 115550.

Kontoleon, K.J., Eumorfopoulou E.A., 2010. The effect of the orientation and proportion of a plant-covered wall layer on the thermal performance of a building zone. Building and Environment. 45, 1287-1303.

Ibrahim, R., Imghoure, O., Tittelein, P., Belouaggadia, N., Chehade, F., Sebaibi, N., Lassue, S., Zalewski, L., 2025. Application of Ventilated Solar Façades to enhance the energy efficiency of buildings: A comprehensive review. Energy Reports. 13, 1266-1292.

Tagybayev, A.; Zhangabay, N.; Suleimenov, U.; Avramov, K.; Uspenskyi, B.; Umbitaliyev, A., 2023. Revealing patterns of thermophysical parameters in the designed energy – saving structures for external fencing with air channels. East.-Eur. J. Enterp. Technol. 4/8, 32-43.

Zhangabay, N., 2024. Development of models and analysis of temperature fields of new energy-saving enclosing structures with an air layer. *E3S Web Conferences*. *474*, 01009.

Zhangabay, N., 2024. Investigation of the impacts of the thickness of the composite material on the temperature regime of energy-saving fencing of the outer wall with closed vertical wind channels. *E3S Web of Conferences*. *474*, 01075.

Gonçalves, M., Figueiredo, A., Almeida, R.M.S.F., 2024. Vicente R. Dynamic façades in buildings: A systematic review across thermal comfort, energy efficiency and daylight performance. Renewable and Sustainable Energy Reviews. 199, 114474.

Zhangabay, N.; Tursunkululy, N.; Utelbayeva, A.; Abdikerova, A.; Sultanov, S., 2025. A Study of Temperature and Humidity Conditions in a New Energy-Efficient Design of a Wall Structure with Air Gaps. *Modelling*. *6(1),* 12.

Zhangabay, N.; Oner, A.; Rakhimov, M.; Tursunkululy, T., Abdikerova, U., 2025. Thermal Performance Evaluation of a Retrofitted Building with Adaptive Composite Energy-Saving Facade Systems. Energies 18(6), 1402.

Alpar, S., Berger, J., Mazuroski, W., Belarbi, R., 2024. Shape optimization of the energy efficiency of building retrofitted facade. Solar Energy. 271, 112437.

Giyasov, A.; Ibraimova, U.; Tursunkululy, T.; Kolesnikov, A., 2024. Construction and climatic certification of an area as a prerequisite for development of energy-efficient buildings and their external wall constructions. Construction Materials and Products. 7 (5). 1.

Ivanović-Šekularac, J., Čikić-Tovarović, J., Šekularac, N., 2016. Application of wood as an element of façade cladding in construction and reconstruction of architectural objects to improve their energy efficiency. Energy and Buildings. 115, 85-93.

Zhangabay, N., Bakhbergen, S., Aldiyarov, Zh., Tursunkululy, T., Kolesnikov, A., 2024. Analysis of

DOI: 10.63550/ICEIP.2025.56.67.028

thermal efficiency of external fencing made of innovative ceramic blocks. Construction Materials and Products. 7 (3). 1.

Borodin, K., Zhangabay, N.Z., 2019. Mechanical characteristics, as well as physical-and-chemical properties of the slag-filled concretes, and investigation of the predictive power of the metaheuristic approach. Curved and Layered Structures, 6(1), P. 236–244.

Zhangabay, N., Giyasov, A., Ybray, S., Tursunkululy, T., Kolesnikov, A., 2024. Field thermovision study of external enclosure for multi-story residential building under climatic conditions of Northern Kazakhstan. Construction Materials and Products. 7 (1). 1.

Zhangabay, N., Giyasov, A., Bakhbergen, S., Tursunkululy, T., Kolesnikov, A., 2024. Thermovision study of a residential building under climatic conditions of South Kazakhstan in a cold period. Construction Materials and Products. 7 (2). 1.

Giyasov, A., Ybray, S., Tursunkululy, T., 2024. Study of heat protection of external envelopes of a residential building in the cold period. E3S Web of Conferences. 542, 06003.

Giyasov, A., Ybray, S., Tursunkululy, T., 2024. Study of heat protection of translucent external envelope in winter period. E3S Web of Conferences. 542, 06005.

Stanevich, V.T., Bulyga, L.L., Vyshar, O.V., Girnis, S.R., Rakhimova, G.M., 2022. Analysis of Energy Efficiency of Building Envelopes of JSC Station EGRES-2. AIP Conference Proceedings, 2559, 050006.

Rakhimova, G.; Zhangabay, N.; Samoilova, T.; Rakhimov, M.; Kropachev, P.; Stanevich, V.; Karacasu, M.; Ibraimova, U., 2024. Computational Research of the Efficiency of Using a Three-Layer Panel Made of Highly Porous Polystyrene Concrete. Materials. 2024, 17(16), 4133.

Ibraimova, U., Suleimenov U., Moldagaliyev A., Buganova S., Jumabayev A., Kolesnikov A.., Tursunkululy T., 2023. Factors affecting extended avalanche destructions on long-distance gas pipe lines: Review. Case Studies in Construction Materials 19, e02376.

,

,

,

,

Tursunkululy, T., N., Avramov, K., Chernobryvko, M., Suleimenov, U., Utelbayeva, A., 2022. Influence of the parameters of the pre-stressed winding on the oscillations of vertical cylindrical steel oil tanks. Eastern-European Journal of Enterprise Technologies, 5(7 (119), 6–13.

2

n state of the vertical mounting joint of the cylindrical tank wall taking into account imperfections. Eastern-European Journal of Enterprise Technologies, 3 (7 (117)), 14–21

Duissenbekov, B., Tokmuratov, A., Yerimbetov, B., 4Aldiyarov, Z., 2020. Finite-difference equations of quasistatic motion of the shallow concrete shells in nonlinear setting. Curved and Layered Structures, 7(1), P. 48–55.

Tursunkululy, T., Avramov, K., Chernobryvko, M., Kambarov, M., Abildabekov, A., Narikov, K., Azatkulov, O. O., 2023. Oscillation frequencies of the reinforced wall of a steel vertical cylindrical tank for petroleum products depending on winding pre-tension. East-Eur. J. Enterp. Technol. 3(7 (123), 14–25.

Code of Rules of the Republic of Kazakhstan 2.04-01-2017. Building Climatology: State Standards in the Field of Architecture, Urban Planning and Construction. Code of Rules of the Republic of Kazakhstan. – JSC “KazNIISA”, LLP “Astana Stroy-Consulting”, 2017. Approved and Enacted on 20 December 2017. 43 p. Available online: https://gos24.kz/uploads/documents/2022-12/sp-rk-2.04-01-2017-stroitelnaya-klimatologiya.pdf (accessed on 20 March 2025).