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ENERGY PERFORMANCE OF RESIDENTIAL BUILDINGS

The problem of the Ukrainian housing stock energy performance is under consideration. Analysis of the outer walling thermal protection condition has been performed for the basic building construction solutions through the example of Poltava. The housing stock is represented by brick, large-block and panel system buildings, erected in the 50–80-th of the last century. The actual values of heat transfer resistance of the outer walls, windows, covers and other building enclosure are 3–5-fold less than the permissible minimum dimension according to the present-day requirements. The article presents recommendations for thermal modernization of the outer walls in accordance with their construction design, attic and basement floors (over the unheated basement), as well as transparent outer structures according to the present-day standard requirements.

Keywords: *thermal modernization, supplementary heat insulation, residential houses walls.*

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ЕНЕРГОЕФЕКТИВНІСТЬ ЖИТЛОВИХ БУДИНКІВ

Розглянуто проблему енергоефективності житлового фонду України. Проведено аналіз стану теплозахисту зовнішньої оболонки основних конструктивних рішень будівель на прикладі м. Полтава. Представлено житловий фонд цегляними, великоблочними та панельними будинками, які збудовані в 50–80 рр. минулого століття. Розраховано дійсні значення опору теплопередачі зовнішніх стін, вікон, покриття та інших огороджувальних конструкцій, які у 3–5 разів менші за мінімально допустимі за сучасними вимогами. Надано рекомендації щодо термомодернізації зовнішніх стін згідно з їх конструктивним рішенням, горищного перекриття та перекриття над неопалюваними підвалами, а також світлопрозорих зовнішніх конструкцій за сучасними нормативними вимогами.

Ключові слова: *термомодернізація, додаткове утеплення, стіна житлового будинку.*

Introduction. Solution of the energy saving problem significantly determines the terms of Ukraine's surmounting the long-lasting economic crisis. Maximum energy saving is reducing dependence on the countries supplying fuel and energy resources, it is minimizing energy-output ratio of national products.

The existing housing stock of the national houses was mainly formed in the postwar Soviet period, when at designing and constructing houses the primary expenditures were to be saved, and the energy exploitation costs were considered as the secondary indications in the ultimate building efficiency calculations. Change of the house-heating technological conditions, caused by the need of maximum energy saving, has lead to the mass-scale discomfort in the exploitation conditions of the residential buildings: low indoors air temperature, high humidity, carcinogenic fungi on the internal structures surface and in the premises air. These issues are requiring the immediate solution due to their great social importance, thus, at analyzing the exploitation properties of buildings, it is necessary to provide not their energy saving, but energy performance.

Entering the European environment expected by Ukraine stipulates enacting of common European regulations and their implementation ways. The major field of development is harmonizing the national standards base [1, 2] with the European Union's requirements in terms of the buildings' energy performance [11] and implementing «Energy strategy of Ukraine up to 2030» in the building construction industry.

Raising the energy consumption efficiency is impossible without taking specific measures in the sphere of building construction.

Due to the necessity of detailing the state forecasts on energy saving in the national economy, data have been updated concerning the energy saving development of the country in accordance with the Energy strategy of Ukraine up to 2030.

According to the above Strategy, in 2030, compared to 2005, the total fuel resources saving due to the engineering factor is estimated to make 128.42 mlnt.r.f. (ton of reference fuel); electric energy saving will make 108.72 bln kW/year; heat energy saving will make 231.87 mlnGcal which totally makes 198.06 mlnt.r.f.

The basic energy saving reserve is reducing energy resources consumption by the residential and public objects which share in the total energy consumption of the civil-engineering industry makes over 80%.

Latest sources of studies and publications review. Many authors devoted their studies to the issues of raising the heat shielding properties of the residential and public buildings' walls to comply the standard regulations requirements. For instance, they were considered in the works [3–5, 9, 10]. Study [6] is devoted to the analysis of the heat-retainer (insulant) type's influence on the humidity status of the walling, the insulant being located on the indoors side of the walling. Study [7] is considering the issues of the basement outer walling heat insulation. Studies [8] are devoted to the issues of the outer walling insulation in the areas of heat-conductive materials inclusions.

Setting parts of the total problem not-solved before. Publications devoted to thermal modernization of the residential houses' outer walling structures do not consider the influence of the panel walls joints on the additional heat insulation layer width. The joint's area occupies a significant part of the panel wall's area, therefore, its structure not taken into account, is leading to errors in determining the additional heat insulation layer width. Besides panel walls, the study considers other most common outer walling types used in residential houses of Poltava.

Setting the problem. The present study was aimed at developing recommendations on the outer walls thermal modernization in the existing residential houses of Poltava. While determining the width of the additional insulant in the panel walls, the influence of the panel walls joint's structure on the value of the heat transfer resistance was taken into account.

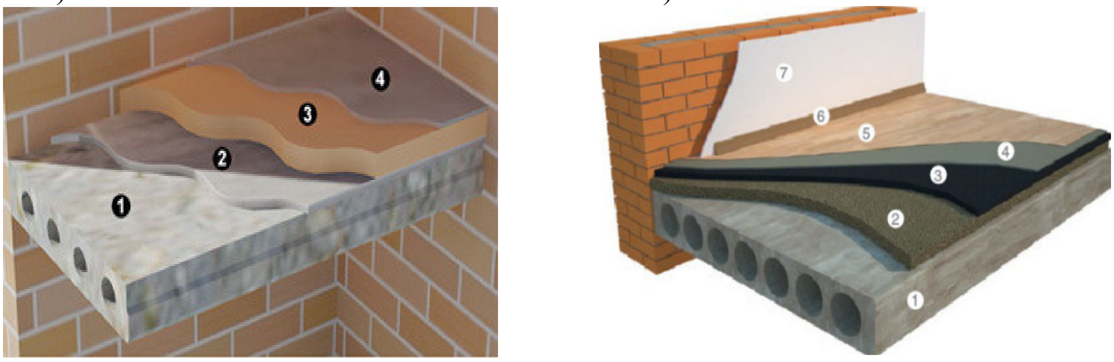
Basic material and the results. The housing stock of Poltava is represented by the brick, large-block and panel system buildings, erected in the 50–80-th of the last century (Fig. 1).

Figure 1 – Residential buildings of Poltava

The present state of residential houses walling thermal protection in Poltava does not comply with the present-day requirements [1]. The actual values of heat transfer resistance of the outer walls, windows, covers and other walling structure are 3–5-fold less than those registered in [1, 2], as the permissible minimum values.

In the Soviet period, the attic floor heat insulation was performed by means of floor filling with keramzit (expanded clay aggregate). The heat transfer resistance of the said structure makes 1.5–2 $m^2 \cdot K/W$. To obtain the standardized heat transfer resistance value (4.95 $m^2 \cdot K/W$) the floor should be insulated with the efficient slab insulant of 200 mm width which is determined by the thermotechnical calculation according to the diagram in Figure 2,a. The unheated basement floor covering structure should have heat transfer resistance not less than 3.75 $m^2 \cdot K/W$ and it should be performed according the diagram in Figure 2, b.

a) b)



a)	b)
1. Floor slab	*1. Floor slab*
2. Vapour barrier insulation	*2. IZOVAT 160 heat insulant*
3. IZOVAT 40 heat insulant	*3. Waterproofing*
4. Sand-cements creed	*4. Reinforced screed*
	5. Floor covering
	6. Skirtboard
	7. Wall

Figure 2 – Recommendations for heat insulation

a – of the attic floor; b– the unheated basement floor

The present-day heat-engineering requirements to the windows stipulate installation of double-glazed insulation windows with the low emissivity glass or the glass chambers filled with argon or krypton. For the city of Poltava, the minimal permissible value of the heat transfer resistance makes 0.75 $m^2 \cdot K/W$, therefore the following glazing variants are recommended: variant 4i-10-4M1-10-4i (double-glazed insulation window with two layers of the low emissivity glass and soft coating and one standard glassplate, the glass chambers filled with air) or variant $4M_1$-10-$4M_1$-10-4K (double-glazed insulation window with one layer of the low emissivity glass and hard coating and two standard glass plates, the glass chambers filled with krypton).

Most walling structures in residential buildings are made of panels, large-blocks and brick. Panels manufactured at Poltava Integrated House-Building Factory (HBF) are illustrated in Figure 3.

a) b)

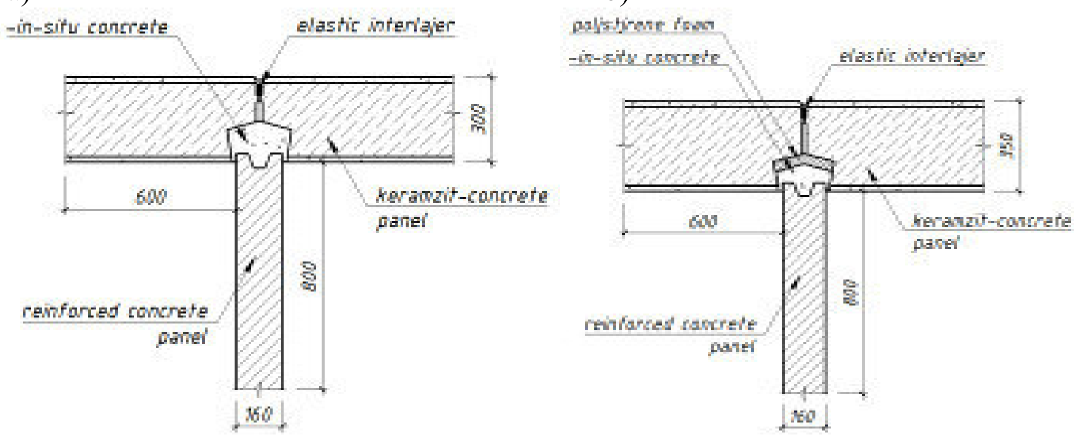


Figure 3 – Wall panels structure

a – 300 mm wide without the thermofiller; b – 350 mm wide with thermofiller

Wall panel is manufactured without the thermofiller (Fig.3, a). Having taken into account the suggestions made by PoltIBI, Poltava Integrated House-Building Factory started producing wall panels of 350 mm width and performing their joints using thermofiller containing polystyrene foam with the density ρ_0 = 50 kg/m^3 and width of 40 mm (Fig. 3, b).

At determining panel walls' thermal protection it is necessary to take into account the panels joints which occupy a significant part of the total panel area. Therefore, the heat transfer resistance calculation should be performed based on the structure's temperature field. The temperature field calculation is performed by means of Elcut program.

Temperature fields of the unheated panel wall are displayed in Figure 4.

Results of determining the panel wall's matched heat transfer resistance are presented in Table 1.

Table 1 – Results of determining the panel wall's matched heat transfer resistance

Panel wall's width, mm	Matched heat transfer resistance of the walling, m^2·K/W	Minimal-temperature on the internal surface, °C	Meantemperature on the internal surface, °C	Minimalpermissiblevalueofthewallingstructure'sheattransferresistance value, m^2·K/ W
300	0.595	12	12.2	3.3
350	0.721	12.9	13.3	

a) b)

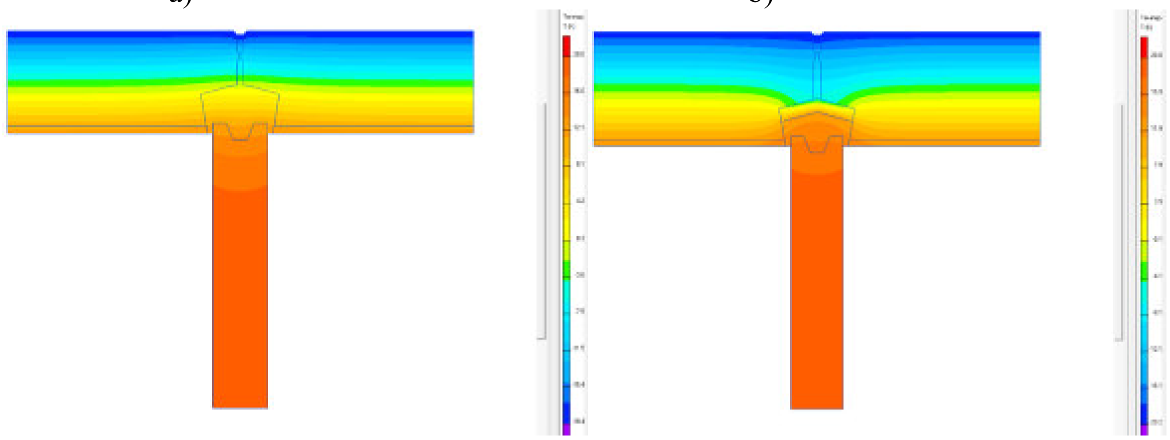


Figure 4 – Temperature field of the unheated panel wall:
a – 300 mm wide without the thermofiller; b – 350 mm wide with the thermofiller

Additional outer heat insulation can be made of the double-density rock wool FASROCKMAX (the outer layer having the density ofρ_0 = 155 kg/m^3, the internal layer's density is ρ_0 = 87 kg/m^3) or of polystyrene foam PCB-C-35 with the density of ρ_0 = 35 kg/m^3. Advantages of the first variantare high exploitation properties, the second variant's merit is its low cost. Results of determining the additional insulation width are presented in Table 2.

Large blocks which were used for building construction in Poltava were made of keramzit with the density of ρ_0 = 1600 kg/m^3. Most of the outer walling structures made of brick have the width of 0.38 m, 0.51 m and 0.64 m. Brickwork of conventional clay brick with sand-cement mortar having the density of ρ_0 = 1800 kg/m^3 was used.

Results of determining the matched heat transfer resistance for large-block and brick walls are presented in Table 3.

Table 2 – Results of determining the additional insulation width

Additional insulation type	Additional insulation width, mm	Walling heat transfer resistance, $m^2 \cdot K/W$	Minimal temperature of the internal surface, °C
Rock wool FASROCKMAX	110	3.433	18.6
Polystyrene foam PCB-C-35	110	3.507	18.6

Table 3 – Results of determining the matched heat transfer resistance for large-block and brick walls

Wall made of:	Wall width, mm	Walling matched heat transfer resistance, $m^2 \cdot K/W$	Minimal temperature of the internal surface, °C	Mean temperature of the internal surface, °C	Minimal permissible value of the walling structure heat transfer resistance, $m^2 \cdot K/W$
blocks	400	0.714	13.2	13.2	3.3
brick	0.38	0.649	12.6	12.6	
	0.51	0.81	14	14	
	0.64	0.97	15	15	

The order of layers location at thermal modernization of the outer walling structures for large-block and brick buildings is illustrated in Figure 5.

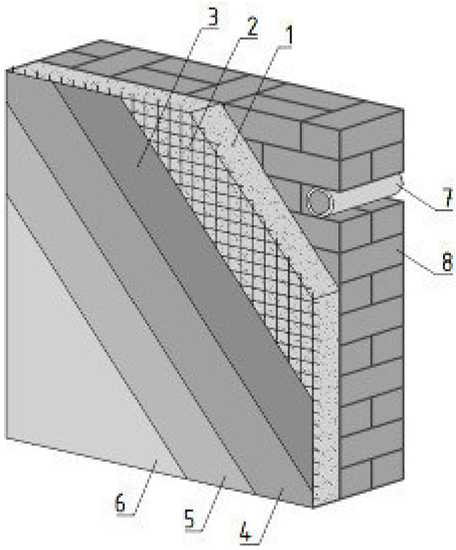


Figure 5 – Façade of the thin-layer plaster system:
1 – heat insulant; 2 – steel grid; 3 – base coating layer; 4 – dubbing layer; 5 – decorative plaster; 6 – masonry paint; 7 – steel anchoring; 8 – wall

Width of the additional heat insulation for the outer walls made of blocks and brick is presented in Table 4.

Table 4 – Results of determining the additional heat insulation width

Additional heat insulation type	Wall material	Wall width, m	Additional heat insulation width, mm	Walling heat transfer resistance, $m^2 \cdot K/W$	Minimal temperature of the internal surface, °C
Rock wool FASROCKMAX	Blocks	0.4	0.11	3.522	18.6
	Brick	0.38	0.11	3.47	18.6
		0.51	0.1	3.373	18.7
		0.64	0.1	3.534	18.6
Polystyrene foam PCB-C-35	Blocks	0.4	0.1	3.346	18.6
	Brick	0.38	0.11	3.544	18.6
		0.51	0.1	3.441	18.6
		0.64	0.09	3.338	18.6

Conclusions:

1. Recommendations on thermal modernization of the existing residential buildings' outer walls in Poltava, to be used in practical activity, have first been developed.
2. To determine the additional heat insulant's width in panel walls the influence of the panel walls joint structure on the matched heat transfer resistance.
3. Over 90% of the existing residential houses in Poltava require thermal modernization.
4. The outer walling heat transfer resistance in most of residential houses is less than the standardized value. In panel buildings it is by 78%–82%, in block ones – by 78% and in brick houses – by 71%–80 % less.
5. The slabs' heat transfer resistance is by 60%–85% and that of the windows is by 70% less than the standardized value.
6. Compliance with the standard regulations of heat transfer needs applying the additional insulant layer 100–110 mm wide, using additional insulation of FASROCKMAX rock wool, and the layer 90–110 mm wide, using PCB-C-35 polystyrene foam. The panel walls joints' influence on the heat transfer resistance should be taken into account while performing thermal modernization of panel walls.
7. Further research should be devoted to studying the influence of all panel walls joints variants on the walling matched heat transfer resistance values.

References

1. *ДБН В.2.6-31:2006. Конструкції будинків і споруд. Теплова ізоляція будівель. – К., Мінрегіонбуд України 2006. – 68 с.*
2. *Зміни № 1 ДБН В.2.6-31:2006. Конструкції будинків і споруд. Теплова ізоляція будівель. Мінбуд України. – Київ, 2013. – 11 с.*
3. *Гагарин В. Г. Теплотехнические проблемы современных стеновых ограждающих конструкцій многоэтажных зданий / В. Г. Гагарин // ACADEMIA. Архитектура и строительство. – М. : МГСУ, 2009. – С. 313 – 318.*
http://istina.msu.ru/publications/article/1111419/
4. *Korniyenko S. V. The Experimental Analysis and Calculative Assessment of Building Energy Efficiency / S. V. Korniyenko // Applied Mechanics and Materials. – 2014. – Vol. 618. – P. 509 – 513.*
http://www.scientific.net/AMM.618.509
5. *Pavlovas V. Energy saving sinexisting Swedish apartment buildings / V. Pavlovas // Chamlers University of Technology. – Göteborg, 2006. – P. 17 – 83.*
http://publications.lib.chalmers.se/publication/11656-energy-savings-in-existing-swedish-apartment-buildings-some-aspects-on-demand-controlled-ventilation

6. *Чернявський В. В. Теплоізоляційно-опоряджувальні фасадні системи як засіб термомодернізації житлового фонду України / В. В. Чернявський, О. І. Юрін, Г. Г. Фаренюк // Ресурсоекономічні матеріали, конструкції, будівлі та споруди: зб. наук. пр. – Рівне: НУВГП, 2008. – Вип. 17. – С. 365 – 372.*
http://www.nbuv.gov.ua/old_jrn/natural/Rmkbs/2008_17/52.pdf
7. *Семко О. В. Вплив теплозахисних заходів на тепловий режим фундаментів та підлоги на ґрунті / О. В. Семко, В. В. Чернявський, О. І. Филоненко // Коммунальное хозяйство городов: науч.-техн. сб. трудов. – Х. : ХНАГХ, 2009. – Вып. №86. – С. 19 – 22.*
http://khg.kname.edu.ua/index.php/khg/article/view/4607
8. *Yurin O.I. Study of heat shielding qualities of brick wall angle with additional insulation located on the outside fences [Electronic resource] / O. I. Yurin, T. A. Galinska // Journal: MATEC Web of Conferences. – 2017. – №116. – Access mode: https://doi.org/10.1051/matecconf/201711602039*
9. *Novelapp roach to 3D therm ography and energy efficien cyevaluation / D. González-Aguilera, P. Rodriguez-Gonzalvez, J. Armesto, S. Lagüela // Energy and Buildings. – 2012. – Vol. 54. – P. 436 – 443.*
http://fulltext.study/article/263674/Novel-approach-to-3D-thermography-and-energy-efficiency-evaluation
10. *Taylor T. Energy efficiency is more than skin deep: Improving construction quality controlin new-buildhousing using therm ography / T. Taylor, J. Counsell, S. Gill // Energy and Buildings. – 2013. – Vol. 66. – P. 222 – 231.*
http://www.sciencedirect.com/science/article/pii/S0378778813004428
11. *EPBD Concerted Action: Implementing the Energy Performance of Buildings Directive (EPBD) featuring country reports 2012. – Porto, 2013.*
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