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MODERN SOLUTIONS OF THERMAL PROTECTION OF EXTERNAL WALLS IN HOUSE BUILDING

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Introduction. A review of literature sources showed many options for insulating external walls in order to ensure the necessary thermal protection requirements for buildings. Insulation is mainly performed using effective thermal insulation materials of two groups: polystyrene (foam, polyurethane foam (PUR), polystyrene foam (PPS), etc.) and mineral wool (glass wool, slag wool, rock wool). Not only the groups, but each of their representatives differ from each other in their heat-shielding and other characteristics, which gives a wide choice of options for insulating external walls to ensure the necessary thermal resistance.

The analysis of literary data showed that mineral wool is considered the most common and economically feasible insulation material for operational and thermal protection purposes in Odessa today. For a monolithic house, the most effective option is a two-layer insulation of the house. In this case, the aerated concrete wall is insulated from the outside with mineral wool and covered with a protective ball of plaster that protects against external actions. According to DBN V.2.6-31:2021 [1], Ukraine's territory is conventionally divided into two climatic zones.

Fig. 1. Map-scheme of temperature zones of Ukraine

For each zone, the minimum permissible value of the coefficient of heat transfer resistance R is regulated - walls, roofs, windows, ceilings and other building structures.

The value of the coefficient of thermal resistance R of different structural elements differs. This is due to the fact that the losses, say, through the walls, roof, windows and doors are different, the data are given in Table 1.

Table 1.

The value of the coefficient R for various structural elements

No	Type of fencing structure	The value of $R_{q\ min}$, $m^2 \cdot K/W$, for the temperature zone	
		I	II
1	Outside walls	4.0	3.5
2	Mixed coatings	7.0	6.0
3	Covering of heated attics (technical floors) and Attic ceilings of unheated attics	6.0	5.5
4	Overlapping over driveways and unheated attics	5.0	4.0
5	Translucent fencing structures	0.9	0.7
6	Zenith skylightes	0.8	0.7
7	External door	0.7	0.6

The purpose and tasks of the work: to point out the possible inconsistency of the real thermal resistance with the calculated operating conditions for the Southern climatic zone. To achieve the goal of the work, the following tasks were set:

1. Measure the moisture content of aerated concrete after production;
2. To determine the thermal conductivity of aerated concrete blocks of different humidity;
3. Calculate the thermal resistance of aerated concrete blocks, considering the moisture content;
4. Compare the obtained thermal resistance with the Ukrainian standards. If inconsistencies are found, select thermal insulation to comply with the norms

Main material and results. To check the thermal resistance of the wall, calculations of the materials used were performed. The calculations were carried out taking into account the use of aerated concrete of different densities with a thickness of 30 cm and mineral wool insulation. In accordance with DSTU 9191:2022 [2] the thermal conductivity of the materials used in the calculation under operating conditions "a" and "b" are presented in Tables 2, 3.

Table 2.

Technical characteristics of aerated concrete of various brands

Aerated concrete brand	D 300	D 350	D 400	D 500
Thickness δ, m	0.3	0.3	0.3	0.3
Density ρ, kg/m^3	300	350	400	500
Thermal conductivity λ, W/(m·°C), under operating conditions "*a*"	0.09	0.1	0.11	0.13
Thermal conductivity λ, W/(m·°C), under operating conditions "*b*"	0.1	0.12	0.15	0.16

To determine the required thickness of the insulation, it is necessary to use the formula $R = \delta/\lambda$, where R is the thermal resistance (m^2·°C/W), δ is the thickness of the insulation in meters, λ is the calculated coefficient of thermal conductivity of the ball material, taking into account the operating conditions of structures that protect (W/(m·°C)).

Table 3.

Technical characteristics of mineral wool

Density ρ, kg/m ^{3}	135
Thermal conductivity λ, W/(m·°C), under operating conditions "*a*"	0.046
Thermal conductivity λ, W/(m·°C), under operating conditions "*b*"	0.049

Based on tabular data, the thermal resistance of a wall made of aerated concrete blocks 30 cm thick was calculated using the above formula, the results are shown in Table 4.

Table 4.

Thermal resistance of aerated concrete of different brands by density

Aerated concrete brand	D 300		D 350		D 400		D 500	
Terms of use	*"a"*	*"b"*	*"a"*	*"b"*	*"a"*	*"b"*	*"a"*	*"b"*
Thermal resistance R, m^2·°C/W	3.33	3.0	3.0	2.5	2.73	2.31	2.0	1.88

As can be seen from the obtained data, the thermal resistance of only the lightest brands (D300 under the conditions of operation "a" and "b", D350 under the conditions of operation "a") of aerated concrete meets the standards and under conditions of operation with a low level of humidity. To meet the standards in our climate zone, the thermal resistance must be higher than 3.5 $m^2 \cdot °C/W$, required by DBN V.2.6-31:2021 "Thermal insulation and energy efficiency" for this temperature zone.

However, in accordance with DSTU B V.2.7-45:2010 [3] The final moisture content of concrete products should not exceed by mass, %: 35 – concrete grades from D200 to D400; 30 – D500 grade concrete made on sand; 25 – concrete grades D600 – D1100, made on sand; 35 – concrete grades D500 – D1100, made on other silica components. The release humidity significantly exceeds the humidity set by the operating conditions, due to which aerated concrete blocks with high humidity can be used in work, which in turn reduces heat-shielding properties. A change in humidity requires recalculation of thermal resistance based on actual data to comply with current regulations.

According to literature data, the value of thermal conductivity of aerated concrete was taken with a higher humidity than the operating conditions "a" and "b", Table 5.

Table 5.

Thermal conductivity of aerated concrete of different brands by density and different humidity

Aerated concrete brand	Thermal conductivity λ, W/ (m °C)							
Humidity *W*, %	**0%**	**4%**	**6%**	**9%**	**14%**	**18%**	**21%**	**27%**
D 300	0.08	0.09	0.1	0.11	0.13	0.15	0.15	0.17
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**13%**	**17%**	**20%**	**24%**
D 350	0.09	0.1	0.12	0.12	0.14	0.16	0.17	0.19
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**11%**	**15%**	**19%**	**22%**
D 400	0.1	0.11	0.13	0.14	0.15	0.17	0.18	0.20
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**11%**	**14%**	**17%**	**21%**
D 500	0.12	0.15	0.16	0.18	0.20	0.22	0.24	0.27

Based on tabulated data, the thermal resistance of aerated concrete was calculated using the above formula at different humidity values, the results are presented in Table 6.

Table 6.

Thermal resistance of aerated concrete of different brands by density at different humidity levels.

Aerated concrete brand	Thermal resistance R, m^2·°C/W							
Humidity W, %	**0%**	**4%**	**6%**	**9%**	**14%**	**18%**	**21%**	**27%**
D 300	3.75	3.33	3.00	2.73	2.38	2.02	1.99	1.76
Humidity W, %	**0%**	**4%**	**6%**	**8%**	**13%**	**17%**	**20%**	**24%**
D 350	3.33	3.00	2.50	2.31	2.14	1.87	1.73	1.58
Humidity W, %	**0%**	**4%**	**6%**	**8%**	**11%**	**15%**	**19%**	**22%**
D 400	3.00	2.73	2.31	2.14	1.88	1.81	1.64	1.53
Humidity W, %	**0%**	**4%**	**6%**	**8%**	**11%**	**14%**	**17%**	**21%**
D 500	2.50	2.00	1.88	1.67	1.43	1.35	1.23	1.10

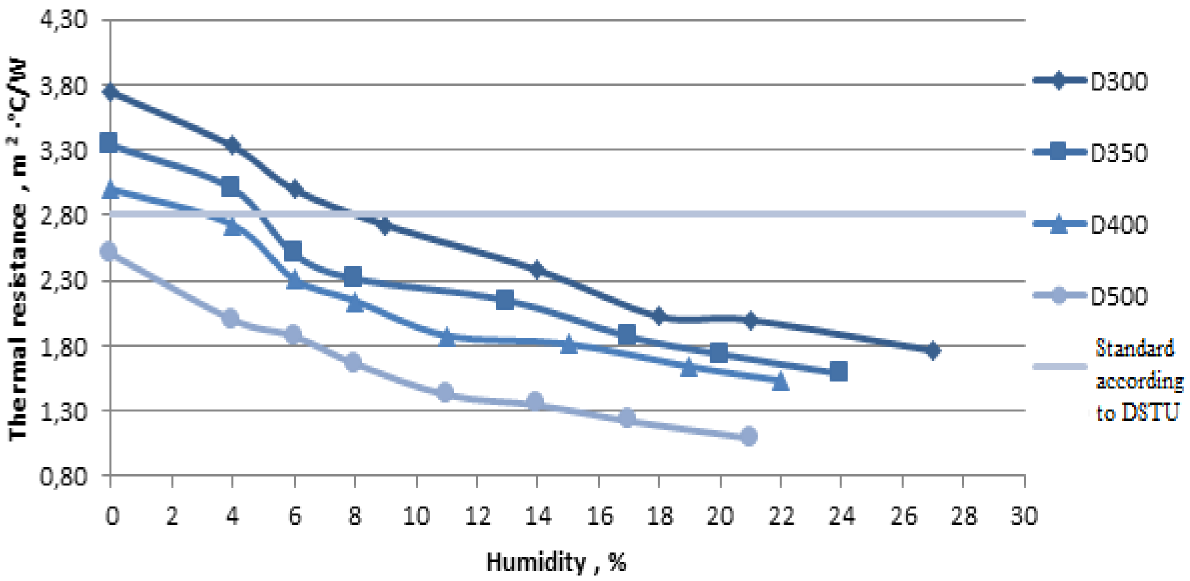

Fig. 2. Thermal resistance of aerated concrete blocks 30 cm thick

As can be seen from the obtained data, aerated concrete blocks (brands D300 with humidity above 6%; D350 with humidity above 4%; D400 with humidity above 0%; D500 with any humidity) cannot fully provide thermal resistance of the structure. Additional resistance can be provided by insulation with mineral plates 5 cm thick.

Thermal resistance of mineral wool under operating conditions "a" is:

$$R = 0{,}05/0{,}046 = 1{,}09 \text{ m}^2\cdot°\text{C/W} \quad (1)$$

The total thermal resistance is considered as the sum of all (in the case of two) separate thermal resistances, the results are shown in Table 7.

Table 7.

Total thermal resistance of aerated concrete of different brands by density at different humidity

Aerated concrete brand	Thermal resistance R_{sum}, m²·°C/W							
Humidity *W*, %	**0%**	**4%**	**6%**	**9%**	**14%**	**18%**	**21%**	**27%**
D 300	4.48	4.42	4.09	3.81	3.47	3.11	3.08	2.85
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**13%**	**17%**	**20%**	**24%**
D 350	4.42	4.09	3.59	3.39	3.23	2.95	2.82	2.67
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**11%**	**15%**	**19%**	**22%**
D 400	4.09	3.81	3.39	3.23	2.96	2.90	2.73	2.62
Humidity *W*, %	**0%**	**4%**	**6%**	**8%**	**11%**	**14%**	**17%**	**21%**
D 500	3.59	3.09	2.96	2.75	2.52	2.44	2.32	2.19

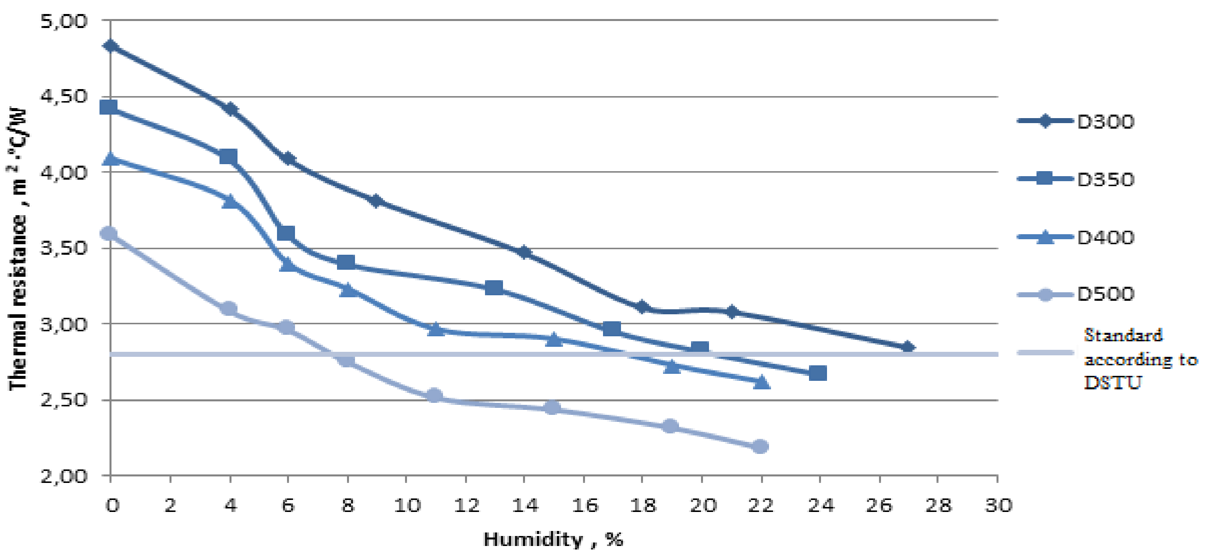

Fig. 3. Total thermal resistance of aerated concrete blocks and mineral wool slabs

Even with a specified insulation, aerated concrete (brands D300 with humidity above 27%; D350 with humidity above 20%; D400 with humidity above 15%; D500 with humidity above 6%) cannot fully provide thermal resistance of the building. To ensure proper thermal resistance in accordance with state regulations, the thickness of the insulation should be increased to 55% of the thickness of the selected mineral wool board used in the experiment.

Conclusions. It is necessary to either dry aerated concrete blocks to match the humidity levels of the intended operating conditions or recalibrate the thermal resistance calculations based on the actual humidity levels.

Summary

Today, there is an urgent global problem of conserving fuel and energy resources, leading to an increased demand for the thermal insulation properties of protective structures. In the southern regions of Ukraine, monolithic residential construction predominates, with aerated concrete commonly used for external walls. The thermal properties of aerated concrete are affected by the density, humidity, and composition of aerated concrete. This inability to always provide the necessary thermal resistance necessitates additional thermal protection for external walls using effective insulation materials.

Анотація

На сьогоднішній день у світі існує актуальна проблема економії паливно-енергетичних ресурсів, наслідком якої є підвищена вимога теплозахисних властивостей конструкцій, що захищають. У Південних регіонах України переважне будівництво це монолітне житлове будівництво, в якому використовують газобетон для зовнішніх стін. На теплотехнічні властивості газобетону впливає щільність, вологість і склад газобетону, у зв'язку з чим його застосування не завжди може забезпечити необхідний термічний опір, у зв'язку з чим зовнішні стіни потребують додаткового теплозахисту ефективними теплоізоляційними матеріалами.

REFERENCES

1. DBN V.2.6-31:2021 "Thermal insulation and energy efficiency".
2. DSTU 9191:2022 "Thermal insulation of buildings method for choosing of insulation material for insulation of buildings".
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