

Analysis of heat-conducting inclusions in exterior walls of residential building

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Abstract. The study is aimed at detecting the zones of major heat losses in exterior walls of residential buildings and developing recommendations on their elimination. The "ELCUT" software program calculated the temperature fields of the external wall under the design temperature of the outside air. The calculation was carried out for three options: the thermal characteristics of the materials of the layers of the outer wall correspond to the design parameters; thermal characteristics of the materials of the layers of the outer wall correspond to the actual measured values; Thermal technical characteristics of the materials of the layers of the outer wall correspond to the actual indicators and additional insulation is made. It is established that with additional insulation, the irregularity of the temperature field on the external surface of the wall is eliminated and normalized thermal resistance complies with the requirements.

1. Introduction

Construction of buildings meeting energy efficiency requirements necessitates making certain decisions on heat protection, which are characterized by significant values of enclosure wall thermal resistance. However, increasing the thermal resistance value for exterior walls does not mean excluding heat-conducting inclusions. The following junctions of building structure elements are the areas of major heat losses:

- joints of blockwork (brickwork) or panels;
- vertical joints of external walls in the area of contiguity of partitions;
- horizontal joints of external walls in the area of floor bearing;
- vertical corner joints of external walls;
- horizontal joints of external walls in the zone of supporting balcony slabs;
- internal and external slopes of windows;

Detecting these areas is possible on the basis of the analysis of temperature fields.

2. The object of the study

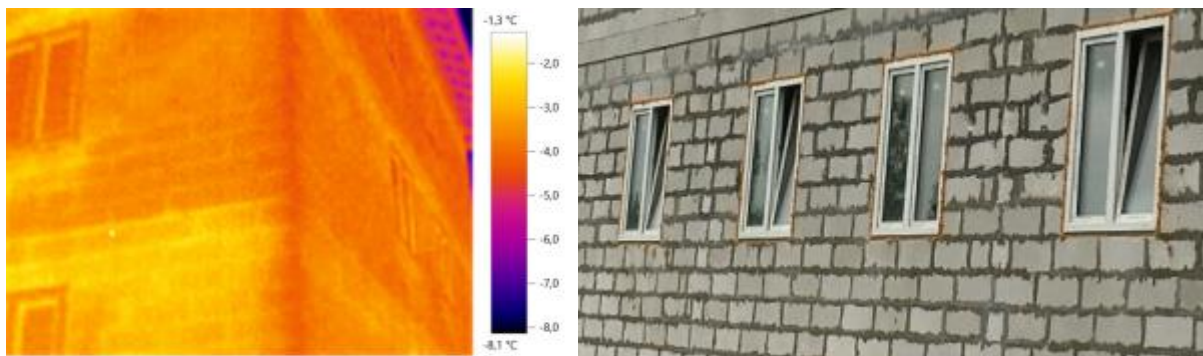
The object of the study is an residential apartment house located on Pskov region, Russia [1,2].

Design climatic conditions of the construction area are shown in Table 1. Internal air temperature is 20°C above zero. According to the initial design, external walls of the building are prescribed of type D500 375 mm thick gas-concrete blocks with subsequent plastering without extra heat insulation (Figure 1).



Table 1. Design climatic conditions [1, 2]

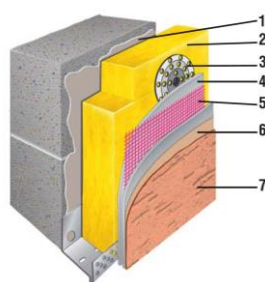
Indicator	Indicator designator	Unit of measurement	Design value
Average outside air temperature for the heating season	t_{hs}	°C	- 1.3
Duration of the heating season	z_{hs}	day/year	208
Degree-day of the heating season	HDD	°C·day/year	4430
Design outdoor temperature	t_{out}	°C	- 26

**Figure 1.** Heat-conducting inclusions in the form of blockwork joints [1, 2]

According to the measurements, the actual value of the adjusted thermal resistance of the exterior wall is $R_{0}^{adj}=1.62 \text{ m}^2\cdot\text{K}/\text{W}$ [1, 2] with normalized value of $2.951 \text{ m}^2\cdot\text{K}/\text{W}$ [3, 4] and lower limit value of $1.859 \text{ m}^2\cdot\text{K}/\text{W}$ [4].

Thermovision inspection of facades of the building within the cold period of its operation revealed a large number of heat conducting inclusions, in particular blockwork joints.

The study is aimed at identifying the zones of the major heat loss in the junctions of outer walls of residential buildings and developing recommendations for their elimination.

**Figure 2.** Facade system *Weber.therm comfort*

1 - adhesive for mineral wool; 2 - facade mineral wool insulation; 3 - dowel; 4 - reinforcing-glutinous mixture; 5 - facade alkali-resistant mesh; 6 - primer; 7 - decorative silicate-silicone facade plaster

The repeated elements of the masonry of the outer walls were considered as the object of research conducted to develop recommendations for bringing the reduced resistance to the heat transfer of the outer wall to the normalized value. To ensure the normalized value of the resistance to heat transfer ($2.951 \text{ m}^2 \cdot \text{K}/\text{W}$), the minimum thickness of the insulation layer is 90 mm. However, it is not necessary that it will be optimal in terms of investment. The values of the expected payback periods

for additional insulation costs for different thicknesses of the thermal insulation layer are have been calculated in previous research [1-2] and are presented in Table 2.

Table 2. Technical and economic comparison [1, 2]

Thermal insulation layer, δ_{ins} , mm	Thermal resistance of the exterior wall, $m^2 \cdot K/W$	Additional capital expenditures ΔI , rub	Operating cost difference ΔE , rub/year	Discounted payback period T_d , year
50	2.788	2 370 306.65	32 999.14	36.1
60	3.013	2 423 794.07	39 544.65	32.9
70	3.250	2 478 025.66	45 470.57	30.7
80	3.475	2 531 268.90	50 337.41	29.2
90	3.713	2 562 384.62	54 834.64	27.9
100	3.950	2 614 488.35	58 791.06	27.0
110	4.175	2 666 592.07	62 124.03	26.4
120	4.413	2 718 707.42	65 273.42	25.9
130	4.650	2 767 264.70	68 101.09	25.5
140	4.875	2 820 554.44	70 525.79	25.2
150	5.113	2 870 297.75	72 853.65	25.0
160	5.338	2 920 041.05	74 867.90	24.8
170	5.575	2 969 784.35	76 817.68	24.7
180	5.813	3 026 620.54	78 608.11	24.6
190	6.038	3 076 363.84	80 174.38	24.5
200	6.275	3 126 107.15	81 705.80	24.5
250	7.438	3 427 845.96	87 790.72	24.8
300	8.600	3 683 655.36	92 230.59	25.2
350	9.763	3 939 464.76	95 613.08	25.7

Based on the technical and economic comparison, the thickness of the mineral wool layer is 200 mm.

3. Results

The calculation of the temperature fields of the exterior wall according to the "ELCUT" program at the calculated outdoor air temperature (Fig. 4) is performed for the following conditions:

- Option 1 - for the design parameters of thermal characteristics of the layer materials of the exterior wall (Figure 3)
- Option 2 - for actual parameters of the layer materials thermal characteristics of the exterior wall (Figure 4);
- Option 3 - for actual parameters of the layer materials thermal characteristics of the exterior wall and additional insulation (Figure 5)

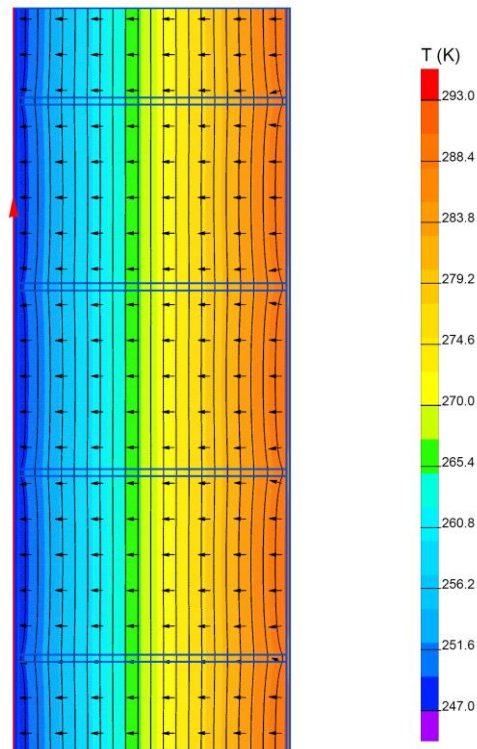


Figure 3. Temperature fields of the exterior walls. Option 1

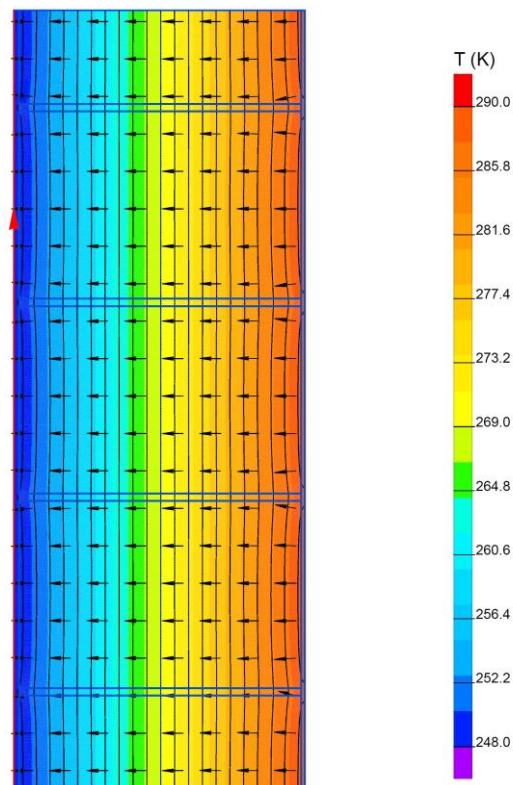


Figure 4. Temperature fields of the exterior walls. Option 2

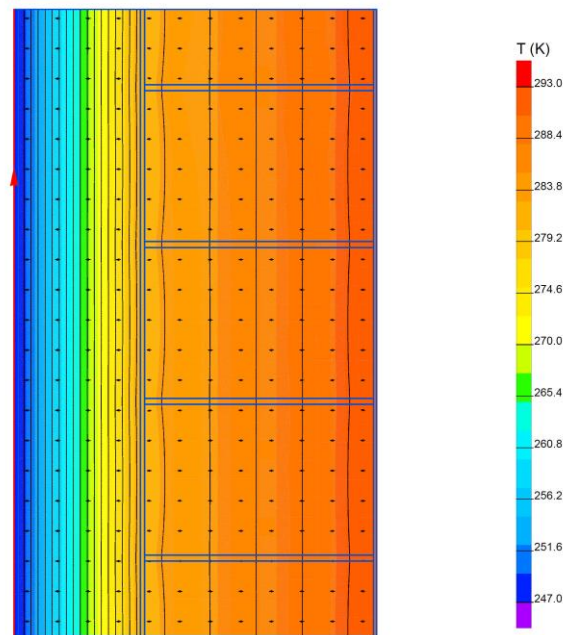


Figure 5. Temperature fields of the exterior walls. Option 2

4. Conclusions

Warming of the outer wall enabled to exclude local areas of high temperatures on the wall surface and provide a reduced resistance to the heat transfer of the outer wall $R_0^{\text{adj}} = 6,161 \text{ m}^2 \cdot \text{K}/\text{W}$.

For comparison, the Figure 6 shows the distribution of temperature over the outer surface of the wall.

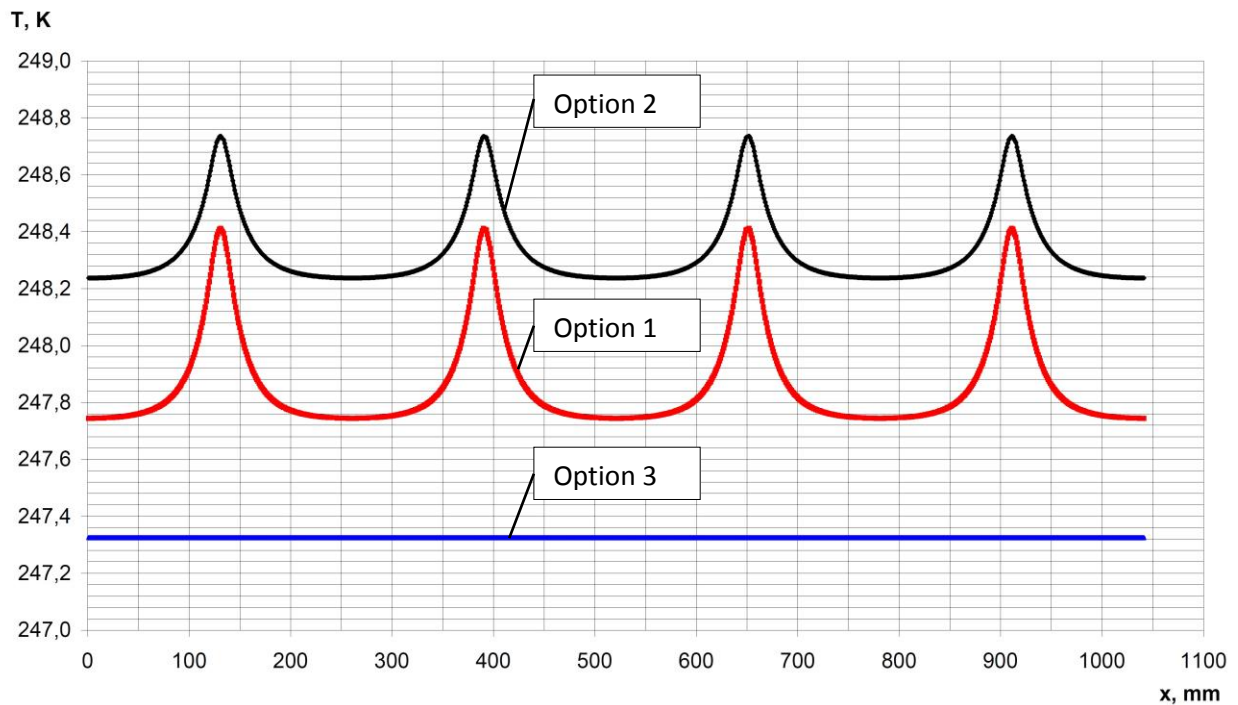


Figure 6. The temperature changes on the outer wall surface for the fragment studied

Thus, with additional insulation, the irregularity of the temperature field on the external surface of the wall is eliminated and normalized thermal resistance complies with the requirements.

References

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