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Analysis of heat loss reduction through window edges

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The constantly increasing fuel prices and worldwide aspirations to reduce environmental pollution are the main reasons for energy savings in buildings. A mere additional insulation of old buildings may decrease heat consumption of these buildings by up to 40%. Currently heat losses through the windows are very high in comparison to heat losses through walls, roofs and floors. They could form about 25% of the total heat losses in buildings, and in some cases when windows are leaky or of poor quality even more.

Theoretical analysis of heat transfer through windows is presented, with the purpose to increase heat insulation capacity.

Key words: heat loss, heat transfer, windows

1. INTRODUCTION

Energy retention and effective solutions related to sustainable buildings have become very important in Lithuania as well as in other countries of the severe northern climate. This topic is discussed by Carmody et al. [1], Vavulo [2] and others. No proper attention was paid to energy effectiveness of buildings in Lithuania two decades ago, therefore the heritage of reconstituted independent Republic of Lithuania in 1990 was buildings with a high energy consumption in comparison with western countries. As the development of Lithuanian economy depends significantly on fuel import, rising of fuel prices as well as rising expenses for heating became a heavy burden to the consumers and the whole society. Therefore Lithuanian government undertook implementation of projects under support of the World Bank, directed to decreasing energy consumption in buildings and increasing energy effectiveness. Surely such projects have a positive impact on the global environmental condition.

2. METHODOLOGY AND CALCULATION RESULTS

In practice, additional building envelope insulation leads to reduction of energy consumption by 40%. According to the present regulations, the heat transfer coefficient for external walls must be changed from 1.2 to 0.5..0.2 W/(m$^2 \cdot$ K) with regard to inside temperature value, for roofs – from 0.55..0.7 to 0.15 W/(m$^2 \cdot$ K), for windows and balcony doors – from 2.4 to 1.6 W/(m$^2 \cdot$ K) [3]. Heat losses through windows are obviously significant, therefore replacing old windows by new ones shows a great economical effect.

In general, the total heat transmission coefficient of a window consists of numerous components:

$$U_W = f(U_1, U_2, U_3), \text{ W/(m}^2 \cdot \text{K)}, \tag{1}$$

where U_1 is the heat transmission coefficient of insulated glass unit; U_2 is the heat transmission coefficient of frame; U_3 is the heat transmission coefficient of window edge.

In the paper, attention is focused on the analysis of heat losses through window edge. The most popular type of window installation during retrofitting of old buildings is presented in Fig. 1. It is a common scheme for buildings built under Soviet requirements.

In real conditions, thermal field at the edge will have an elliptical and not a circular form as is seen in Fig. 1, therefore with a certain approximation we can assume that the length of an arc of heat flow is

$$S = k \cdot \pi \cdot r = 2,36 \cdot r, \ m, \tag{2}$$

where k is the coefficient determined in consideration of thermal field ellipsis [4] (assumed k = 0.75); r is the radius, m (it is significant from r = 0.04 m to r = 0.15 m).

Then the elementary area of heat flow will be:

$$dA = l \cdot dr, \text{ m}^2, \tag{3}$$

where l is the perimeter of the window edge, except the windowsill, m.

The windowsill is not included into the calculation.

In order to simplify the following calculation, heat loss (heat flow) is determined for 1 linear meter of the edge (l = 1.0 m).

The heat transmission coefficient can be calculated according to Þukauskas [5]:

$$U = \left(\frac{1}{\alpha_i} + \frac{\delta}{\lambda} + \frac{1}{\alpha_{out}} \right)^{-1}, \text{ W/}\left(\text{m}^2 \cdot \text{K}\right). \qquad (4\text{–}1)$$

In equation (4–2) the thickness of the layer δ is replaced with the length of the arc of heat flow S. Therefore the heat U value for a window edge without thermal insulation will be:

$$U = \alpha_i + \frac{\lambda}{S} + \alpha_{out}, \text{ W/}\left(\text{m}^2 \cdot \text{K}\right), \qquad (4\text{–}2)$$

where λ is heat conductivity of the external wall, W/(m · K); (brick wall is assumed with the value of λ = 0.87); α_I, α_{out} are the coefficients of surface heat exchange, W/(m² · K), (α_i = 8,7, α_{out} = 23.2).

Heat flow through an elementary element of window edge without thermal insulation:

$$dQ = U \cdot dA \cdot \Delta t, \ W, \qquad (5)$$

where Δt is the temperature difference between heated space and outdoor air (t_i = +18 °C) and outdoors (t_{out} = –23 °C) [6]; dA is the elementary area, m², U is the heat transmission coefficient, W/(m² · K).

Substitute the determined data into expression (5):

$$dQ = 3.69 \cdot l \cdot \Delta t \frac{dr}{1.374 \cdot r + 23.6 \cdot r^2}, \quad \text{W/m}. \qquad (6)$$

The heat flow Q through the linear length of the window edge without thermal insulation, when the length of the heat flow S is varying from r = 0.04 m to r = 0.19 m (Fig. 1) will be equal to

$$Q = 3.69 \cdot l \cdot \Delta t \int_{0.04}^{0.19} \frac{dr}{13.6 \cdot r^2 + 1.374 r} = 69.4 \text{ W/m}. \qquad (7)$$

Heat losses will occur in the rest part of the window edge which is 0.35–0.15 = 0.2 m as well, but the effect will be not considered in the further calculations because the value will not exceed 15% from the value in the main part of the wall.

The total value of heat flow through the window edge without thermal insulation:

$$\Sigma Q = 1.15 \cdot Q = 1.15 \cdot 69.4 = 79.8 \text{ W/m}. \qquad (8)$$

Figure 2 presents the possible way to attach additional insulation on the wall in order to reduce heat losses.

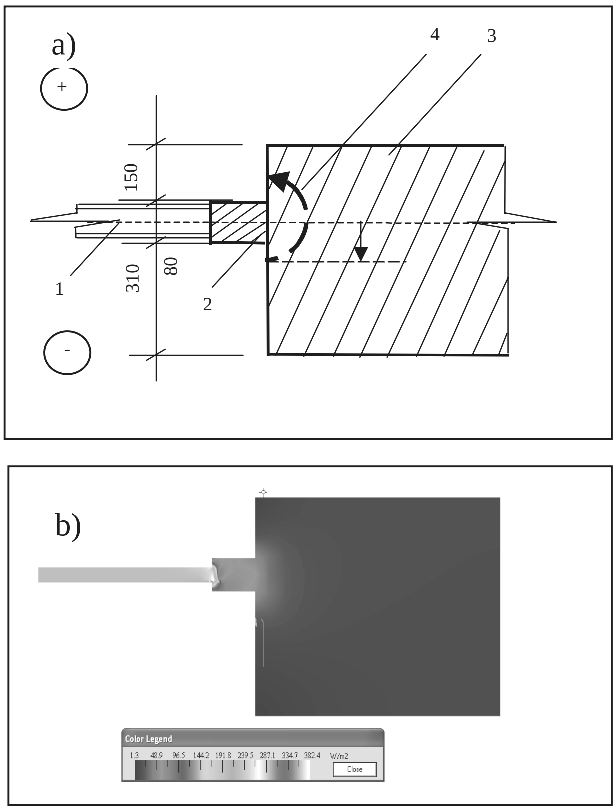

Fig. 1. Scheme of window installation in the wall (*a* – construction sketch; *b* – distribution of heat flow, simulated by the THERM 5 calculation program). *1* – glazing, *2* – window frame, *3* – masonry wall, *4* – arched trajectory of heat flow

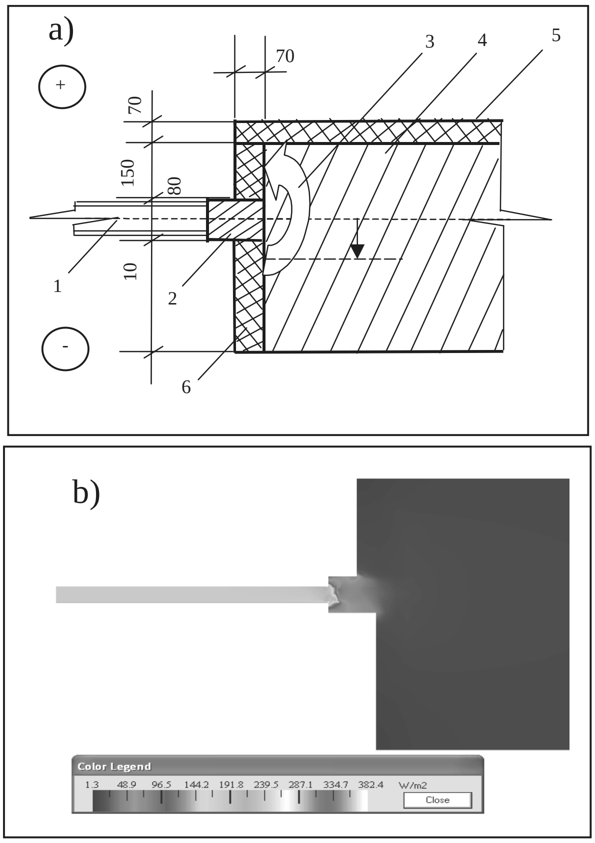

Fig. 2. Additional insulation scheme for windows: (*a* – construction sketch, *b* – distribution of heat flow simulated by the THERM 5 calculation program). *1* – insulating glass unit, *2* – frame, *3* – trajectory of heat flow insulation, *4* – masonry wall, *5, 6* – assumed polystyrene foam with λ = 0.046 W/(m · K)

In this case, the heat transmission coefficient U (4–2) and heat flow Q (7) will be:

$$U = \alpha_i + \frac{\lambda}{S} + \frac{\lambda_{insul}}{\delta_{insul}} + \alpha_{out} = \frac{20 + 23.6 \cdot r}{8.7}, \quad \mathrm{W/(m^2 \cdot K)}, \quad (9)$$

$$Q = 3.69 \cdot l \cdot \Delta t \int_{0.04}^{0.19} \frac{dr}{23.6 \cdot r^2 + 20r} = 11.4 \ \mathrm{W/m}. \quad (10)$$

The total heat flow through the additionally insulated window edge at the presumption made above (8) will be:

$$\Sigma Q = 1.15 \cdot Q = 1.15 \cdot 11.4 = 13.1 \ \mathrm{W/m}.$$

3. CONCLUSIONS

1. Additional insulation of window edges enables a six fold reduction of heat losses through this part of the building envelope as well as improving the thermal conditions.

2. It is possible to save approximately 500–600 kWh of heat for an average window during the heating season under Lithuanian climate conditions.

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References

1. Carmody J. et al. Residential Windows: a Guide to New Technologies and Energy Performance. New York–London: W. W. Norton & Company, 2000. 232 p.
2. Âàâóëî Í. Ì., Ïîâûøåíèå òåïëîçàùèòíûõ ñâîéñòâ îêîí ïðè èõ ðåìîíòå è ðåêîíñòðóêöèè çäàíèé // Ýíåðãîñáåðåæåíèå. 1999. ¹ 1.
3. STR 2.05.01:2005 „Pastatø aitvarø ðiluminë technika“. Vilnius, 2005.
4. LBNL calculation software THERM 5.
5. Æóêàóñêàñ À. A. Êîíâåêòèâíûé ïåðåíîñ â òåïëîîáìåííèêàõ. Ìîñêâà: Íàóêà, 1982. ×. 1.5. Êîýôôèöèåíò òåïëîïåðåäà÷è.
6. RSN 156–94 „Statybos klimatologija“. Vilnius, 1995. 136 p.

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ÐILUMOS NUOSTOLIØ PER LANGUS MAÞINIMO ANALIZË

S a n t r a u k a

Tyrinëjant ðilumos nuostoliø pasiskirstymà per standartinio dydþio langus nustatyta, kad per angokraðèius netenkama daugiau ðilumos nei per ástiklintàjà dalá. Ðiame darbe atlikta ðilumos nuostoliø per lango angokraðèius analizë ir pateikti pasiûlymai jiems sumaþinti. Taip pat apskaièiuoti lyginamieji ðilumos nuostoliai per neðiltintus ir apðiltintus lango angokraðèius. Nustatyta, kad pagal pasiûlytà schemà apðiltinus angokraðèius, lyginamuosius ðilumos nuostolius galima sumaþinti net 6,1 karto, t. y. nuo 79,8 iki 13,1 W/m.

Raktaþodþiai: šilumos nuostoliai, šilumos perdavimas, langas

Ýäìóíäàñ Èñÿâè÷þñ, Âëàäèñëîâàñ Ñòàïîíêóñ, Àíäðþñ Þðeë¸íèñ

ÀÍÀËÈÇ ÓÌÅÍÜØÅÍÈß ÒÅÏËÎÏÎÒÅÐÜ ×ÅÐÅÇ ÎÊÎÍÍÛÅ ÏÐÎÅÌÛ

Ð å ç þ ì å

Èññëåäîâàíèÿ òåïëîïîòåðü ÷åðåç îêîííûå ïðîåìû æèëûõ çäàíèé ïîêàçàëè, ÷òî ñóììàðíûå òåïëîïîòåðè ÷åðåç ñòûê ðàìà–ñòåíà ÿâëÿþòñÿ áîëåå çíà÷èòåëüíûìè ïî ñðàâíåíèþ ñ îñòåêëåííîé ÷àñòüþ. Â íàñòîÿùåé ðàáîòå ïðèâåäåí àíàëèç ïðîöåññà ïåðåõîäà ïîòîêà òåïëà ÷åðåç ñòûê îêîííàÿ ðàìà–ñòåíà, ïðåäñòàâëåíû ïðåäëîæåíèÿ ïî óâåëè÷åíèþ òåðìè÷åñêîãî ñîïðîòèâëåíèÿ ñîïðèêàñàþùèõñÿ ñ îêíîì ïîâåðõíîñòåé îãðàæäåíèÿ è óäåëüíûå òåïëîïîòåðè ÷åðåç óòåïëåííûé è íåóòåïëåííûé ñòûê. Óñòàíîâëåíî, ÷òî ïî ïðåäëàãàåìîé ñõåìå óòåïëèâ ñîïðèêàñàþùèåñÿ ñ îêíîì ïîâåðõíîñòè, óäåëüíûå òåïëîïîòåðè ìîæíî óìåíüøèòü â 6,1 ðàçà, ò. å. îò 79,8 äî 13,1 W/m.

Êëþ÷åâûå ñëîâà: òåïëîïîòåðè, òåðìè÷åñêîå ñîïðîòèâëåíèå, îêíî