HEAT LOSSES DECREASING POSSIBILITIES THROUGH BUILDINGS WINDOWS

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Abstract. The publication contains the research of heat losses decreasing possibilities through buildings windows. Several solutions are found. One solution is to place two windows in one window opening by three-glass packages each with a certain distance to create the air camera. That air camera as an insulator decreases heat losses through windows, decreases cold bridges, and in sunny days it will be heated up due to the greenhouse effect, saving the heat for a longer time and supply it to rooms. The second solution is to stick addition glasses to the window frame from both sides to create additional air gaps increasing the thickness of the window pane that way decreasing heat loses through windows by increasing the thermal resistance of the window.

Keywords: heat loses, windows, window opening, solar heat energy, greenhouse effect, heat saving.

Introduction

Windows are one of the most important building elements that create significant heat losses, respectively 10 to 15 % [1]. To decrease heat losses double doors have been used long time ago. That method is rarely used to decrease heat losses through windows and window openings. More and more progressive window constructions are worked out by using multilayer glass packages. They become more weighty and expensive. To decrease the heat flow, air between the glasses is replaced by argon, krypton and other gasses. But the most progressive window constructions cannot decrease heat losses to be the same as insulated building walls can.

There are several possibilities to improve window thermal resistance. For example, using double solar control coating, it is possible to achieve significant reduction of heat losses until 10 $kWh \cdot m^2$ for North oriented windows and also to gain heat from the Sun radiation during the heating season from South oriented windows [2]. These methods are rather complicated, therefore in this paper other variants are investigated how to decrease heat losses through windows and window openings. For insulated walls the relation of the wall thermal conductivity and window heat conductivity is rather big. This means that window opening is an essential place how to reduce total heat losses through the external wall overall. The thickness of insulated walls essentially increases and the window opening depth also increases. It means that there is a possibility to use this window opening as an insulating layer if this space is closed.

One possibility is to fit up two window frames in the window opening. If the wall is insulated from outside, then the outer frame has to be fitted near the outside surface of insulation by using low heat conductivity brackets. The second frame has to be fitted near the inside wall surface. The air gap between the inside and outside windows serves as heat insulation. It is also necessary to consider possibilities to open windows and possibilities to reach the space between the windows.

Such system was constructed in a house in Ludza, Latvia. During the experimental research it was established that in conditions when the sun does not shine directly in the window, the average temperature in the air gap was approximately mean between the indoor and outdoor air temperatures, but when the sun shines directly in the windows, the greenhouse effect was observed. In this case the air in the gap builds a barrier for heat flow. Air temperature can exceed the temperature of the indoor air and then the inside surface of the window works as a heater for the indoor air.

The second cheaper and more common possibility is to attach additional glasses to both sides of the existing window frame. This method gives two additional air gaps with the thickness similar to the window glass package thickness thereby decreasing heat losses.

Experimental research of the innovative window system efficiency

The described systems were built in Ludza town in office premises of the Association "EKOtehnoloģijas". The walls of the first room are built from aero concrete blocks by thickness 25 mm and insulated from inside by 250 mm thick layer of polystyrene. For inside finish pinewood planking with thickness 30 mm was used. In the South side window opening two windows were built in (Fig. 1). Both of them have 3 glass packages with a separated frame 16 mm between the glasses, filled with argon. Selective glass CE EN1279-5:05+A210. Thereby the space between the windows is 400 mm.

Calibrated temperature measuring devices were mounted in the space between the windows, inside the room and outside of the building. Measurements were performed in January of 2015. Temperatures were measured by interval 1 hour. As an example in Table 1 and Fig.3 there are measurement results given for the 17th January. There were not clouds on that day and the sun was shining but rather low on the horizon. The indoor temperature was maintained constant using heating devices.

The walls of the second room are built from horizontal wooden beams with thickness 200 mm and insulated from inside with 200 mm layer of polystyrene. The window with two glasses package was built in the window opening. Two additional glasses were stuck to both sides of the window frame. Thereby there was developed a construction that consists of: glass 4 mm-air gap 20 mm – glass 4 mm – argon gap 15 mm – glass 4 mm – air gap 20 mm – glass 4 mm (schematically displayed in Fig. 2).

Analysis of the data obtained from experimental researches of innovative window systems

The thermal resistance of the window opening increases when the 2 window system (Fig. 1) is installed. The thermal resistance of each used triple package window windows according to given technical parameters is $R_w = 0.55\ \mathrm{m^2 \cdot {}^\circ C \cdot W^{-1}}$. When using two windows, the closed air gap is formed with thickness 400 mm. The thermal resistance of this gap is assumed $R_{ag} = 0.19\ \mathrm{m^2 \cdot {}^\circ C \cdot W^{-1}}$ [5].

The total thermal resistance is:

$$R_{WT} = 2 \cdot R_W + R_{ag} = 2 \cdot 0.55 + 0.19 = 1.29\ \mathrm{m^2 \cdot {}^\circ C \cdot W^{-1}}. \quad (1)$$

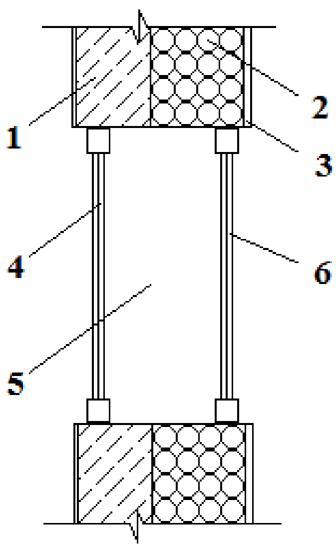

Fig. 1. **Window opening with 2 windows:** 1 – aero concrete wall; 2 – polystyrene insulation; 3 – wood finish; 4 – outside window; 5 – air space; 6 – inside window

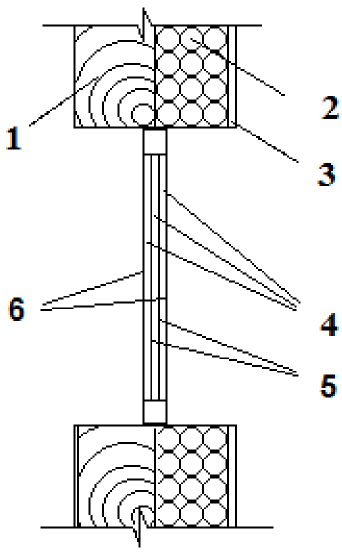

Fig. 2. **Window opening with additional glasses:** 1 – wood wall; 2 – polystyrene insulation; 3 – wood finish; 4 – three air gaps; 5 – original glasses of package; 6 – additional glasses

It means that the thermal resistance of the window opening increases, the thermal transmission coefficient in this case is $U = 0.775\ \mathrm{W \cdot m^{-2} \cdot {}^\circ C}$ and it is even better than it is recommended for passive or low energy buildings ($U_R = 0.8\ \mathrm{W \cdot m^{-2} \cdot {}^\circ C}$) [3]. According to Latvia building regulations LBN 003-01 "*Būvklimatoloģija*" (Building climatology) average heating season outdoor temperature in Daugavpils (the nearest place to Ludza in these regulations) is $t_o = -1.3$ ºC and the durability of the heating season is 205 days and nights, average necessary temperature in premises is $t_i = 18$ ºC, then the specific decrease of heat losses relating 1 $\mathrm{m^2}$ of the window surface is:

$$\Delta q_h = q_w - q_T = \frac{t_i - t_o}{R_w} - \frac{t_i - t_o}{R_{WT}} = \frac{18-(-1.3)}{0.55}\frac{18-(-1.3)}{1.29} = 20.1\ \mathrm{W \cdot m^{-2}}, \quad (2)$$

where q_w – specific heat losses throw window opening with one window , W·m^{-2};
q_T – specific heat losses throw window opening with two windows, W·m^{-2}.

The increasing of the window opening thermal resistance in comparison with one window system is 2.3 times (of 130 % more). That means approximately 99 kWh of heat will be saved on every 1 m^2 of the window opening surface during the heating season. If the costs of heat in town are 70 EUR for 1 MWh, it is possible to save 6.9 EUR from 1 m^2 window surface per 1 heating season. If the installation costs approximately 100 EUR·m^{-2} the payback time will be approximately 14.5 years.

But that is not the only benefit. If the window opening is located on the side irradiated by the Sun, it is possible to observe the greenhouse effect. The intensity of solar radiation in winter days without clouds can reach 700 W·m^{-2} [4]. It grounds possibilities to utilize solar heat. The air between the two windows gets warm and reaches temperature that exceeds the air temperature in premises. In this case it is possible to receive additional heat energy that is supplied to the air in premises. When the temperature of the air gap between the windows exceeds the indoor temperature the heat flows through the inside window to the indoor air, but if the temperature of the air gap is less than the indoor temperature, then heat losses take place and the heat flows from indoors to the air in the air gap. The amount of heat depends on the temperature difference and duration of sunshine. It is also possible to make a system with airflow windows. In this case the air flow will pass between the windows or between glasses and it will be possible to supply more heat to indoor air by blowing air, and also to recover heat by combination with ventilation [1].

During sunny days in January, February and March 2015 experimental measurements of temperatures were performed in days, when the Sun shined to windows. The example of the measurement results is given in Fig. 3. In the given example from 11.00 till 17.00 o'clock the heat amount q_p flows towards the indoor air making heat gain, but in the rest of the time from 17.00 till 11.00 q_l towards outdoors causing heat losses.

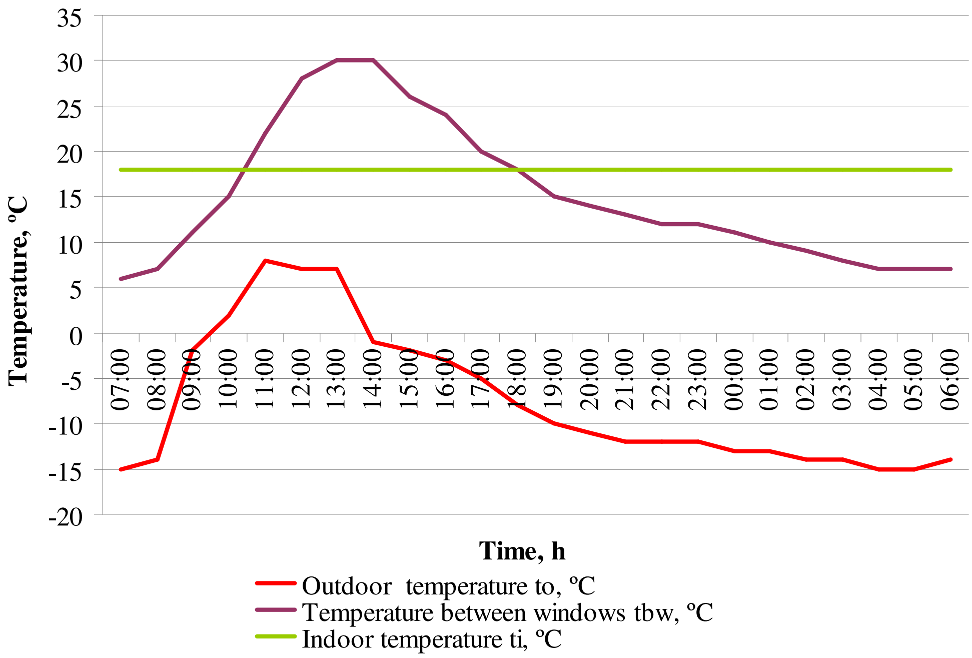

Fig. 3. **Example of temperature changes in air gap (Fig. 1) during 24 hours (17th Jan 2015)**

To illustrate the weather conditions (concretely Sun status) during obtaining the data, an example of numeric data with comments is shown in Table 1. The air in the air gap receives heat from the greenhouse effect, for that reason the temperature of this air is important to evaluate the heat gain and therefore its changes were measured during 24 hours cycles.

Table1

Temperature measurements for south faced window opening with two windows (Fig. 1) during 24 hours

Time, h	Outdoor airtemperature t_o, ºC	Temperature between windows t_{bw}, ºC	Comments
7:00	-15	6	Night
8:00	-14	7	Daybreak
9:00	-2	11	Daybreak
10:00	2	15	Sunlit, no clouds
11:00	8	22	Sunlit, no clouds
12:00	7	28	Sunlit, no clouds
13:00	7	30	Sunshinesonappr. 20 % ofwindowarea
14:00	-1	30	Sunshinesonappr. 20 % ofwindowarea
15:00	-2	26	Sundoesnotshineonwindow
16:00	-3	24	Twilight
17:00	-5	20	Night
18:00	-8	18	Night
19:00	-10	15	Night
20:00	-11	14	Night
21:00	-12	13	Night
22:00	-12	12	Night
23:00	-12	12	Night
0:00	-13	11	Night
1:00	-13	10	Night
2:00	-14	9	Night
3:00	-14	8	Night
4:00	-15	7	Night
5:00	-15	7	Night
6:00	-14	7	Night

The additional acquired amount of heat q_p during given 24 hours is:

$$q_p = \frac{t_{bwe} - t_i}{1000 \cdot R_W} \cdot \tau = \frac{25.7 - 18}{1000 \cdot 0.55} \cdot 6 = 0.084 \text{ kWh}, \quad (3)$$

where q_p – heat amount that flows towards indoor air (heat gain), kWh;
t_{bwe} – average temperature in the air gap between the windows, when it exceeds indoor air temperature (according to numeric data in Tab.1 it is +25.7 ºC);
t_i – indoor air temperature, +18 ºC;
R_w – thermal resistance of the window, $m^2 \cdot ºC \cdot W^{-1}$;
τ – duration, h.

Heat losses q_l during 24 hours is:

$$q_l = \frac{t_i - t_{bwb}}{1000 \cdot R_W} \cdot \tau = \frac{18 - 10.7}{1000 \cdot 0.55} \cdot 18 = 0.2387 \text{ kWh}, \quad (4)$$

where q_p – heat amount that flows towards outdoor air (losses), kWh;
t_{bwb} – average temperature in the air gap between the windows, when it is below indoor air temperature (according to numeric data in Tab. 1 it is +10·7 ºC).

In this specific case the additional benefit in 24 hours in relation to heat losses is:

$$q_p = \frac{q_p}{q_l} \cdot 100\% = 35.5\% \ . \quad (5)$$

This benefit is variable and depends on many conditions an also differs from season to season, but totally we can evaluate it as positive acquisition in the total balance of building heat consumption.

Performing the second way to increase the heat saving effectiveness by sticking additional glasses on both sides of the window frame (Fig. 2), closed air cameras are formed on both sides. Together with two additional glasses they increase the thermal resistance of the window. The thickness of air cameras or air gaps is 2 cm. Thereby it is possible to calculate the thermal resistance of a window with two additional glasses R_{WGl}:

$$R_{WGl} = R_W + 2R_{ag} + 2R_{gl}\,, \tag{6}$$

where R_{ag} – thermal resistance of the air gap, m²·ºC·W⁻¹ (R_{ag} = 0.15 m²·ºC·W⁻¹) [3];

R_{gl} – thermal resistance of glass, m²·ºC·W⁻¹ ($R_{gl} = \frac{\delta_{gl}}{\lambda_{gl}} = \frac{0.004}{1.0} = 0.004$ m²·ºC·W⁻¹);

δ_{gl} – thickness of glass, m;

λ_{gl} – thermal conductivity factor of glass, W·m⁻¹·ºC⁻¹.

And the thermal resistance is:

$$R_{WGl} = 0.55 + 2\cdot 0.15 + 2\cdot 0.004 = 0.858 \text{ m}^2\cdot{}^\circ\text{C}\cdot\text{W}^{-1}. \tag{7}$$

Then the specific decrease of heat losses Δq_hrelated to 1 m^{2}of the window surface if temperature conditions are the same as in previous calculations of heat flow is:

$$\Delta q_{dh} = q_w - q_{Gl} = \frac{t_i - t_o}{R_w} - \frac{t_i - t_o}{R_{WGl}} = \frac{18-(-1.3)}{0.55}\frac{18-(-1.3)}{0.858} = 12.5\ \text{W}\cdot\text{m}^{-2}\,, \tag{8}$$

where q_{Gl} – specific heat losses through the window with two additional glasses, W·m⁻².

The thermal resistance of the window increases for approximately 56 % in comparison with the window before improvement. That means approximately 61.5 kWh of heat is saved to every 1 m^2 of the window surface during 205 heating season days. If the costs of central heating in town are 70 EUR for 1 MWh, it is possible to save 4.3 EUR from every 1 m^2 window surface per 1 heating season. The costs of mounting additional glasses are approximately 20 EUR per m^2. That means the time of payback is approximately four and half years.

Conclusions

1. Installation of an additional second window in the window opening with distance 40 cm between it and the existing window increases thermal resistance of the window opening approximately 2.3 times or 130 % in comparison with window opening with one window.
2. When the sun shines, it is possible to use the greenhouse effect in the air gap between two windows to supply additional heat to indoor air when the air gap temperature exceeds the indoor temperature. It also forms a heat barrier that eliminates heat losses through the window. This effect is variable and it depends on the weather conditions during years.
3. By sticking additional common window glasses with thickness 4 mm on both sides of the window frame, it is possible to decrease heat losses through the window for approximately 1.56 times or 56 %.The payback time of such system is approximately 4.5 years.
4. Due to higher temperature of the window surface the comfort conditions in premises increase.

Acknowledgments

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