7th International Building Physics Conference

IBPC2018

Proceedings

SYRACUSE, NY, USA

September 23 - 26, 2018

Healthy, Intelligent and Resilient Buildings and Urban Environments

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Roof Windows for Passive Houses – What Can Be Improved?

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ABSTRACT

In general, skylights and roof windows in pitched roofs can be described as the critical components of buildings concerning heat losses, risk of surface condensation, increased risk of overheating of rooms behind etc. This is very sensible task especially for passive house solutions. The paper informs about studies analyzing the importance of these relatively small areas in the building envelope and more detailed in pitched roof of a passive house. One of the key problems is the position of roof window within the pitched roof construction.

Second part of the paper comments results of detailed analysis of thermal performance for different combination of frame type and glazing. These studies are performed hand in hand with development works. It is documented that such approach can lead to promising results, reducing the thermal transmittance of roof window to 0.7 – 0.5 W/(m^{2}K). If we consider the real roof window quality including the thermal couplings due to window installation such thermal transmittance stays safely bellow 0.9 W/(m^{2}K).

KEYWORDS

roof window, pitched roof, thermal transmittance, passive house

INTRODUCTION

It is known that roof windows are the weakest components of building envelope. Therefore they are quite unpopular by passive house designers. Nevertheless, they have to be used in some cases and the resulting increased heat transmission must be compensated in order to achieve the passive house criteria. The database of components certified for passive houses (PHI, 2018a) contains only 2 products (for comparison: there are 218 products of passive house suitable vertical windows in this database). The problem with roof window quality is rather complex and starts with the non-optimal position of such window in the pitched roof: Perimeters of window frames are more or less exposed to outdoor condition (Fig.1). Typically for passive houses, no heating body bellow the window is placed there. This can be a critical issue for avoiding the risk of surface condensation in some details. Even if the heating body would be used its temperature is controlled according to heating demand which does not guarantee the presence of warm air movement near to window surface. From both mentioned reasons only the very best roof windows should be used, carefully checked for very low thermal transmittance and for high enough surface temperature.

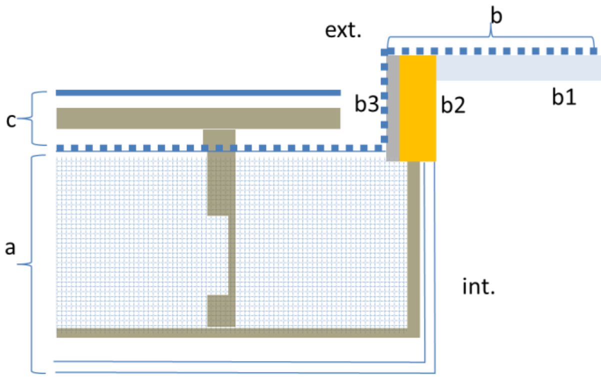

Figure 1. Schematic horizontal cross section of a typical position of roof window in a pitched roof. Dotted line represents the surfaces exposed to the exterior temperatures.
(a typical pitched roof assembly (from interior): indoor gypsum board lining, OSB boards, mineral wool thermal insulation, protective membrane open to water vapor diffusion), b roof window (simplified): b1 glazing unit, b2 frame and sash, b3 possible additional thermal insulating shield), c roof covering)

THERMAL TRANSMITTANCE

Thermal transmittance of the roof window installed in a pitched roof can be described in an extended way as follows (in accordance with PHI, 2018b):

$$U_{w,inst.} = \frac{A_g . U_g + A_f . U_f + \Sigma(\psi_g . l_g) + \Sigma(\psi_w . l_w)}{A_g + A_f}$$

where the $\Sigma(\psi_w . l_w)$ describes the effects of installation. It is illustrated in Fig.2 for hypothetical window of excellent quality: Assumed thermal transmittance of glazing 0.60 W/(m^{2}K), frame U_f 0,60 W/(m^{2}K), thermal bridges of glazing edge expressed by linear thermal transmittance ψ_g 0,03 W/(mK), thermal bridge due to installation in the roof (ψ_w 0,05 W/(mK), considering the reference window size 1.14 m x 1.40 m. It can be seen that for improvements of roof windows all parts are of a high importance: glazing, frame and installation method and overall geometry.

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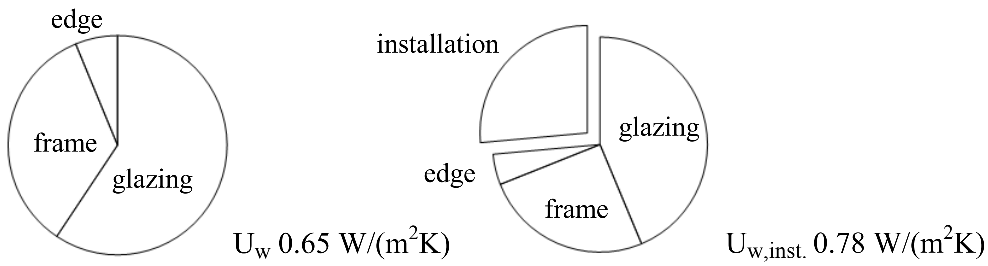

Figure 2. Result of a study for excellent roof window in typical position in pitched roof (see Fig.1). Heat transfer of window (left), heat transfer of window including installation in the pitched roof (right) based on 2D calculations for all relevant cross sections.

IMPORTANCE OF ROOF WINDOWS IN HEAT LOSS OF BUILDING ENVELOPE

Two studies were performed to show the influence of roof window in the overall transmission heat loss of a building envelope for simple single family house. Thermal transmittances used here are based on standard requirements (CSN 73 0540-2, 2011) as well as on recommendations for passive buildings published there. First study (Fig.3, Tab.1) deals with the whole building envelope. The second one (Tab.2) is focused to pitched roof only – with or without windows, considering different thermal qualities. At the pitched roof of 140 m^2 for a passive house is the opaque part responsible for 77 % and the roof windows (6 pcs a 1 m^2) for 23 % of heat losses respectively. This corresponds to and ¼ increase of heat losses compared to the roof without windows.

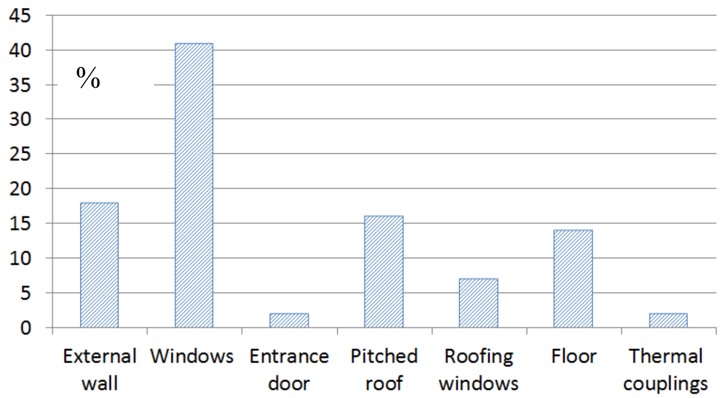

Figure 3. Distribution (%) of transmission heat loss for simple single family house with typical values needed for reaching passive house level.

Table 1. Data for case study – Effect of 6 roof windows in the building envelope.

	Thermal transmittance [W/(m^2K)]	Area [m^2]
External walls	0.15	120
Windows in walls	0.8	46
Doors	1.0	2
Pitched roof	0.10	134
Roof windows (6pcs a 1m^2)	0.8	6
Floor	0.25	100
Overall effect of thermal couplings between building components	+2 %	--

Table 2. Distribution of transmittance heat loss for a pitched roof of the family house with 6 roof windows. Alternative **A** corresponds to traditional solution around year 2000, alternative **B** for passive house quality roof with traditional roof windows, alternative **C** for passive house quality with high performing windows.

	Thermal transmittance	Heat transfer coefficient [W/K]	Heat transfer coefficient [%]		Overall increase [%] (100 % = no windows)
A					
Roof	0.3 W/(m^{2}K)	40.2	69	69	
Roof windows	1.8 W/(m^{2}K)	10.8	19	} 31	
Thermal coupling by installation	0.3 W/(mK)	7.2	12		
Total		58.2	100		139
B					
Roof	0.1 W/(m^{2}K)	13.4	49	49	
Roof windows	1.5 W/(m^{2}K)	9.0	33	} 51	
Thermal coupling by installation	0.2 W/(mK)	4.8	18		
Total		27.2	100		194
C					
Roof	0.1 W/(m^{2}K)	13.4	77	77	
Roof windows	0.6 W/(m^{2}K)	3.6	21	} 23	
Thermal coupling by installation	0.02 W/(mK)	0.5	2		
Total		17.5	100		125

DETAILED STUDY

A roof window in typical geometry, usual opening system (horizontal pivot casement) and typical installation in the roof was the subject of thermal analysis during our real development process (UCEEB, 2017) (Figure 5). Frame combining wood (assumed thermal conductivity 0.12 W/(mK)) and hard polymer parts (0.04 W/(mK)) together with two types of glazing (Ug 0.30 and 0.50 W/(m^{2}K)) units were used. Installation is assumed to be carried out using thermal insulating installation frame in the roof (demonstrated here by block of extruded polystyrene thickness 100 mm) or traditionally without such additional frame. Two geometries of interior side lining are assumed: perpendicular to the window or symmetrically slanted (opened) to the interior with an angle of 45°. All data are based on 2D calculations of heat conduction for 4 typical cross sections of windows and related to the reference size 1.14 m x 1.40 m. The thermal transmittance of respective frames and linear thermal transmittance of glazing edges were calculated according to EN ISO 10 077-2. Adiabatic boundary layer was set according to EN ISO 12 567-2. The ratio of glazed area to full projected area of the window is 0.63.

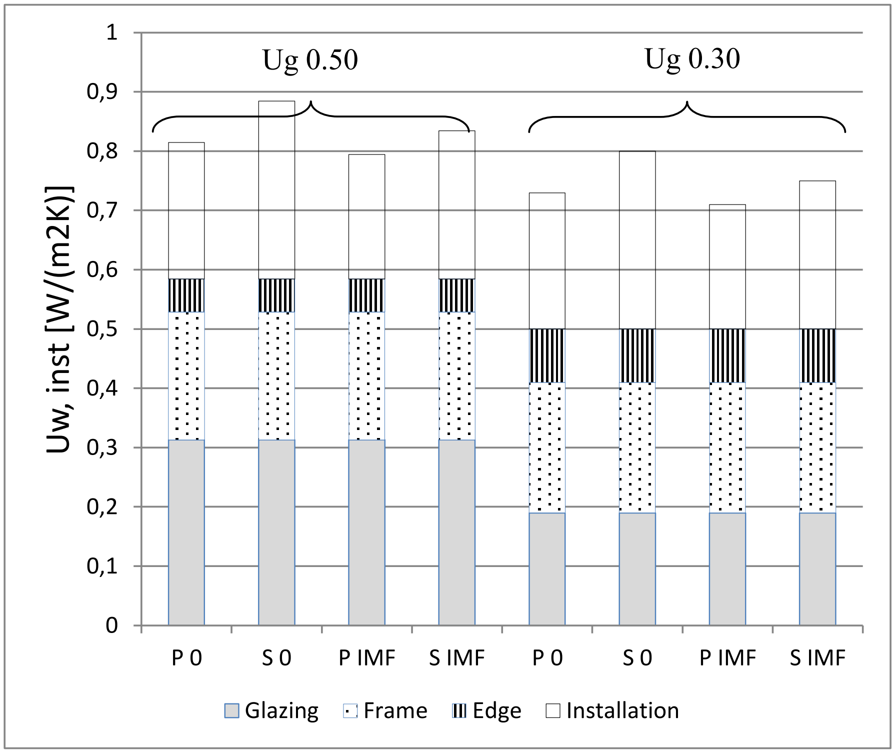

Figure 5. Thermal transmittance of roof windows with the newly developed frame (U_f 0.59 W/(m^{2}K)) and two types of glazing (Ug 0.30 and Ug 0.50 W/(m^{2}K) respectively). (P for perpendicular, S for slanted side lining, IMF for insulating mounted frame)

The results presented in Fig. 5 can be summarized as follows: Even with the (still un-usual) best glazing unit (U_g = 0.30 W/(m^{2}K)) and optimized window frame (U_f = 0.59 W/(m^{2}K)), the U-value of the window installed in typical configuration (P 0) is 0.72 W/(m^{2}K). With a standard triple-glazed unit (U_g = 0.50 W/(m^{2}K)) the overall U-value rises to 0.88 W/(m^{2}K).

The thermal coupling due to installation, which can be hardly avoided, plays a significant role in both cases ($\psi_w \cdot l_w$ = 0.23 W/(m^{2}K)).

The additional thermal insulating frame (IMF) has effect only in combination with slanted interior lining (S), where it lowers the thermal transmittance of about 0.05 W/(m^{2}K). The installation with slanted interior lining (S 0) has higher thermal transmittance of about 0.05 W/(m^{2}K) compared to perpendicular case (P 0). However, this solution may still be preferable due to better distribution of daylight.

RESULTS

The relative high influence of roof window for overall thermal transmittance was identified. In order to reach the passive house criteria the increased thermal loss even by the best possible roof windows has to be compensated. It is advantageous to combine the best glazing with a frame having the thermal transmittance in the same range. Best option seems to be the use of a high performing insulation material directly in the frame. In order to reduce the negative impact of the installation in the roof additional installation components (mounting frames) can be used or (better) the window frame itself should contain corresponding continuing thermal insulation material on its perimeter.

The geometry of side lining (widening to interior) has no significant negative influence on heat loss due to limited amount of thermal insulation there (UCEEB, 2017).

CONCLUSION AND OUTLOOK

Consistent and complex application of building physic instruments can effectively accompany ongoing development works. All parts of future roof window should be optimized in order to achieve plausible results: Of critical importance is the frame in terms of material choice and shape. The form of installation has a big influence on the final result as well.

Based on these findings our research will continue in following directions:
a) Developing and testing of a real solution together with industrial partner according to already performed theoretical and experimental studies (not published here). It is expected that the frames will be alternatively made of hard polymer with appropriate surface layer (high pressure laminate. veneer lumber etc.) or made of high quality wood profiles combined with hard polymer.
b) Continuation in theoretical and experimental research concerning heat transfer at surfaces of windows in order to guarantee no condensation risk there, especially for situations without possible positive effects of heating bodies placed bellow.
c) Continuation (UCEEB, 2017) in day-lighting experimental studies for optimum size and installation. The side lining widened to interior can support better distribution of daylight. In general, such measure can lead to sufficient daylight with smaller window areas which has an additional energy saving effect.
d) Studies about optimum shading and estimation of overheating risks.

ACKNOWLEDGEMENT

This work has been supported by the Ministry of Education, Youth and Sports within National Sustainability Programme I, project No. LO1605 and by Technology Agency of the Czech Republic, project No. TH01021120.

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Nomenclature

U thermal transmittance W/(m^2K)
A area m^2
l length m
ψ linear thermal transmittance W/(m.K)

indexes

g glazing, f frame, w window, inst installed