A quasi-box window concept to improve the thermal-insulation property of old windows - case study

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Abstract. The article presents the concept of improving the thermal insulation properties of a window thanks to the installation of an additional internal window. The resulting quasi-box window can be an alternative to the thermo-modernization of windows by replacing them. Measurements of the thermal parameters of the prototype and the unmodified window were made in an office space during its standard use. A quantitative and qualitative analysis of the compared solutions was made.

1 Introduction

One of the basic features of the sustainable construction is the reduction of energy consumption both during the construction and operation of buildings. In newly built buildings, weight is attached to the thermal resistance of partitions and modern thermal insulation materials are used [1]. Solar energy solutions are increasingly being used [2–7]. Thermo-modernization works are carried out in existing buildings. In contrast to the typical external partitions (walls of roof, etc.), improving the thermal insulation of the window due to its multifunctionality is an expensive and troublesome procedure for a building's users. Most often it boils down to its replacement with new ones with satisfactory thermo-physical parameters. Research is carried out on innovative solutions in the field of the thermal insulation properties of windows [8–10]. Modern materials are used in this field, such as: aerogel [1, 11], PCM (phase change material) [12–15], TIMs (Transparent insulation materials), vacuum glazing, etc. These solutions are relatively expensive and are primarily dedicated to newly built low-energy buildings. In existing buildings, the window needs to be replaced. Accompanied by: noise and dust emission, the need to temporarily shut down the room for service, the cost or the issue of interference in the appearance of the facade can be a serious constraint for the investor. Less onerous, and in many cases an adequate way, can be replacement of the glass itself. However, this way is not always possible. It requires a wing construction adapted to the greater thickness of the double-chamber pane and to carry a larger mass, by about 10 kg/m².

A significant increase in thermal resistance, comparable to a modern window, can also be achieved thanks to a window installation with insufficient thermal resistance,

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an additional window. The double glazed windows refers to the popular so-called sash window. The construction of the additional window can be made of wood, PVC or aluminum profiles. In the case of assembly from the inside of the building, older frames and wings can be used, in relation to which there are no excessive requirements in terms of tightness, resistance to atmospheric influences, etc. As a result, a construction is created for the quasi- box window. To allow access to the window space, the height of the window profile of the additional window should be smaller than the distance between the window sill and the bottom of the outer window sash (Fig.1).

Fig. 1. The principle of determining the height of the additional window frame: 1–existing window frame, 2–wing of the existing window, 3–pane of the existing window, 4–frame of the additional window, 5–wing of the additional window, 6–pane of the additional window.

2 Description of the test stand

The quantitative assessment of the impact of installing an additional window on the thermal parameters of the resulting unit was carried out in an office space during its typical operation. The room had two windows glazed on the south side with one-chamber glass with a heat transfer coefficient $U_g = 1.1 \text{ W/m}^2\text{K}$. An additional window with the same heat transfer coefficient was added to one of the windows. The resulting quasi-box window and unmodified window were equipped with temperature and heat flux density sensors (Fig. 2). The registration of monitored parameters was carried out using an ALMEMO 2890-9 recorder. Additionally, an NEC TV thermal imaging camera was used to carry out the observations.

Fig. 2. Test stand: a) a diagram of the measuring system, b) view.

3 Results and Discussion

The influence of the applied solution on the heat loss through the window illustrates a graph of changes in the density of heat fluxes on the inner surfaces of glass panes (Fig. 3). The graph shows the changes observed during three sunny days, of which one was cloudy. On the single window, higher instantaneous values of heat flux density were observed as a result of solar radiation on the glass during the day. Heat gains, although they achieve higher instantaneous values, may not be consumed due to the possibility of causing discomfort in the room. On detail "A" in Fig. 3, the dynamics of heat flux density changes is presented. The quasi-box window generates heat gains about 2.5 hours longer than a single window. In this case, the positive property can be considered as accompanying the reduction of fluctuation in the stream, which is distributed over time. The above observation is confirmed by a thermogram (Fig. 4) made from the interior of the room about 1.5 hours after sunset. The temperature profile line shows more than 3 degrees higher in quasi-box window temperature. The Thermal operation of windows at night is illustrated by detail "B" of the graph (Fig. 3). In this case, less heat loss was observed by more than 10.0 W/m² in the quasi-box window compared to the unmodified window. The empirical approximate values of heat transfer coefficients in the central part of the pane were determined by calculating the ratio of the heat flux density to the air temperature difference on both sides of the window. They were respectively 1.15 W/m²K for a single window and 0.77 W/m²K for a quasi-box. The reduced value of the heat transfer coefficient of the quasi-box unit, with good accuracy corresponds to the inverse of the sum of the thermal resistance of the connected windows.

Fig. 3. Graph of heat flux density changes of compared windows.

Fig. 4. Thermogram showing the effect of heat emission from absorbed solar radiation through a quasi box window (view from the room side): a) thermogram, b) temperature profile-line.

The thermogram shown in Fig. 5, which was made at night from the outside, confirms the relations described above between the tested windows. In addition, it shows a significant effect of heat loss through the window frame. In the case of an unmodified window, they are approximately 60% larger than glass losses, compared to the quasi-box window.

Fig. 5. Thermogram of tested windows (view from outside): a) thermogram, b) profile line of temperature.

On the presented graphs of temperature changes in the examined windows (Fig. 6), the high value of air temperature in the interstitial space of the quasi-box window, which exceeded 60°C, is noteworthy. It was caused by the action of solar radiation. Such a high value was influenced by the lightweight construction of curtain walls. Observations conducted for one year did not show problems related to thermal stresses. However, they can not be excluded in situations where the heat is absorbed by the walls. In these cases, the use of a PCM phase change material can be considered in the interspace area. It will reduce excessive temperature increase and also reduce heat loss proportional to its value outside the window.

Fig. 6. Temperature changes in the compared windows.

Fig. 7. presents a graph of changes in the relative humidity in the space between the windows. In the period of research the humidity did not exceed 50%. This condition was possible due to the generally low humidity in the room in which the window was installed. However, when analyzing temperature fluctuations in the interspace space (Fig. 6, Fig. 7), one can notice its local minima at a level even below 10°C. In conditions of relative humidity of about 52% at 20°C, this temperature drop corresponds to the dew point.

Fig. 7. Graph of changes in relative humidity and temperature in the air space between the quasi-box window and the single window.

4 Conclusions

Observations have shown the effect of an additional window on the reduction of the heat transfer coefficient was from 1.15 to 0.77 W/m²K, i.e. ca. 33%. Considering that this value was determined from the heat flux density measurement in the central part of the pane, it can be assumed that the degree of reduction of the coefficient taking into account the influence of the frame and linear thermal bridges is higher. The reduction of the heat transfer coefficient quasi-box window has been confirmed by the reduction of the heat flux density at night, around 10 W/m².

The positive aspects of the solution include the limitation of temperature fluctuations on the inner surface of the pane and the elongation in relation to the normal sheath, the time of room heating with the heat from the absorbed solar radiation. It seems advisable to place a container with phase-changing material in the space of the window. The heat stored in this way will limit the amplitude of temperature changes in the space between the panes. In this way, it reduces the risk of excessive thermal stresses and a drop in temperature below the dew point.

An additional advantage of the solution may be an increase in the acoustic insulation of the solution. In this respect, there are plans to carry out a study in the future.

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