

# Increase the internal surface temperature to eliminate surface condensation on the window

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**Abstract.** One of the most critical places in buildings in terms of physical thermal properties are windows. This is the most frequent place where the temperature drops below the dew point and surface condensation, or mould, develops. The work deals with the study of the surface temperature courses at the critical points of window glazing and connection joints and the subsequent improvement of the initial unsatisfactory condition by using a patented technology, a conductive material without further intervention in the structure. In the case of a very unsatisfactory condition, a heating resistance wire was attached to the bar, which in combination with the bar distributes the heat to a wider area. The evaluation of the surface temperature increase was performed in a steady-state thermal analysis with fixed boundary conditions and then with the influence of the flow in a room with the heater placed under the window.

## 1 Introduction

Energy consumption in buildings is a highly debated issue and is given a lot of emphasis. The measures on existing buildings issued by the European Commission are leading to improvements in the energy efficiency of buildings. In buildings, heat sources are being changed to reduce the primary energy from non-renewable sources (e.g., by installing photovoltaic systems), or additional insulation is being added. Therefore, the proportion of thermal bridges in the total heat loss of the building increases [1, 2].

Buildings become insulated and airtight. However, this brings with it moisture problems on the inside of the building envelope. The first approach to solving moisture problems is consistent ventilation. In the case of a failure inside of the structure (most often the contact of two structures or materials), due to thermal bridge (accidental or systematic), the lowest internal surface temperature should be monitored to eliminate surface condensation [3, 4].

Windows are still the weakest part of the building envelope, either on their surface or in the connection joint between the frame and the wall [5]. The following work deals with the detail of the window sill and jamb of a wooden window frame with double glazing without external frame insulation. To increase the internal surface temperature at the window connection joint, aluminium bars of different thicknesses were used in combination with heating resistance wires of different capacities. The jamb model was studied in a computer simulation of a steady-state thermal analysis and verified by thermal imaging camera.

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Furthermore, the details of the parapet were studied in terms of airflow and the effect on the surface heat transfer coefficient.

## **2 Methodology**

In the following work, the detail of the window jamb of a wooden window frame with double glazing placed on an uninsulated solid brick was analysed. The window connection joint is identified as a critical location. To rehabilitate the unsatisfactory existing condition, an aluminium sheet was chosen in 3 thicknesses, 0.3 mm, 0.6 mm and 0.9 mm curved in an L-shape. An insulated heating resistance cable was attached to this bar with 3 power ratings - low power 5 W/m, 10 W/m and 15 W/m. This cable has a temperature resistance of up to 70 °C.

An insulated heating wire was used with a 230 V supply cable placed on the surface of the aluminium bar. The alloy of metallic resistive materials changes its resistance only very slightly when exposed to high temperatures, and therefore it is suitable as a heater.

The principle of resistance wires is simple. The cable heats up as the electric current passes through it. Instead of a heat storage layer of concrete around the cable, such as in floors, we use the conductivity of the bar to distribute the temperature in the critical area. If a conductive product is used to distribute the heat, higher cable powers are possible.

All the details were modelled in Ansys Workbench, by finite element method. The selected detail of the jamb was analysed in the steady state thermal analysis module. Due to the high conductivity of the bar, temperature stabilisation happens very quickly, therefore, the non-stationary time behaviour of the detail was not modelled. Verification of the results was done by measuring with a thermal imaging camera.

The airflow around the sill in a room with a heating element placed under the window was then studied. The flow model was specified as k-ε, the exterior temperature was -15 °C, the initial interior temperature was 15 °C. The heating temperature of the radiator was chosen for a standard iron radiator 75 °C. The constructions are in a state without insulation; therefore, it is not possible to consider low-temperature heating [6], [7].

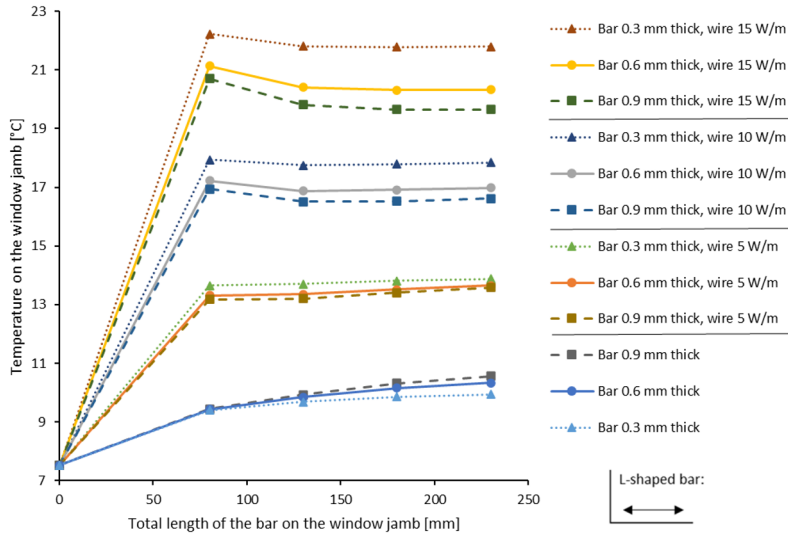
## **3 Results**

The work is based on previous publications in *Young Scientist 2022*, where the selected bar was studied on 3D detail of a window [8].

### **3.1 Window jamb – Steady-State Thermal Analysis**

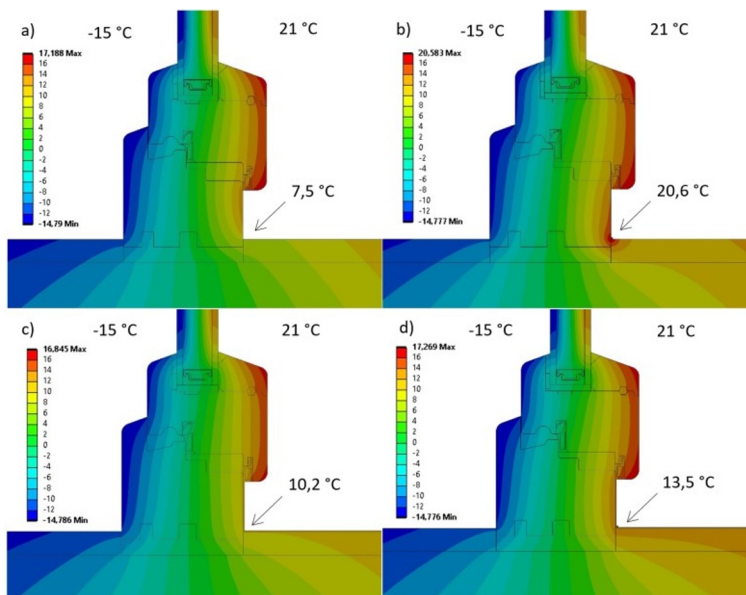
A detail of a wooden window with double glazing installed on uninsulated brickwork made of solid brick was analysed. Figure 1 shows a graph of the temperature dependence at the jamb connection joint on the total (unfolded) length of the aluminium bar. Three thicknesses of aluminium sheet were modelled (0.3 mm - dotted course, 0.6 mm - solid course and 0.9 mm - dashed course) and 3 heating resistance wire powers - 5, 10 and 15 W/m. At length 0 is the temperature of the detail without the bar and cable modification.

The lower three temperature waveforms correspond to the detail with the bar without the temperature wire in place. Higher temperature profiles match the temperature of the bar with the resistance wire. The resistance wire placed on the bar increases the surface temperature up to 21.8 °C from the original 7.5 °C; only the aluminium bar without the wire reaches temperatures up to 10.5 °C.



**Fig. 1.** Graph of the temperature dependence of the connection joints at the window jamb on the developed length of the bar

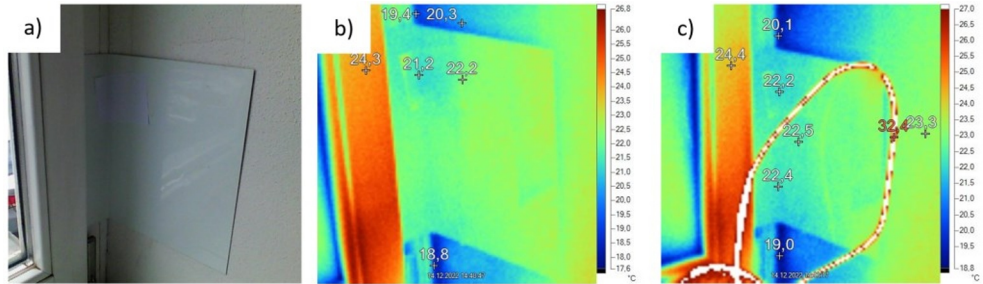
In Figure 2 we can see the temperature waveforms in the detail of the jamb. Figure 2a shows the detail without modification with a temperature at the connection joint on the interior side of 7.5 °C, Figure 2b shows the detail with the resistance wire with a temperature at the wire of 20.5 °C. In Figure 2c is a detail with an L-shaped aluminium bar, 0.6 mm thick, with a developed length of 180 mm (30 mm on the frame and 150 mm on the plaster jamb). The lowest internal surface temperature at the connection joint is 10.1 °C. In Figure 2d, a resistance wire of 5 W/m is placed on the bar from the previous detail. The initial temperature at the connection joint is 13.5 °C.



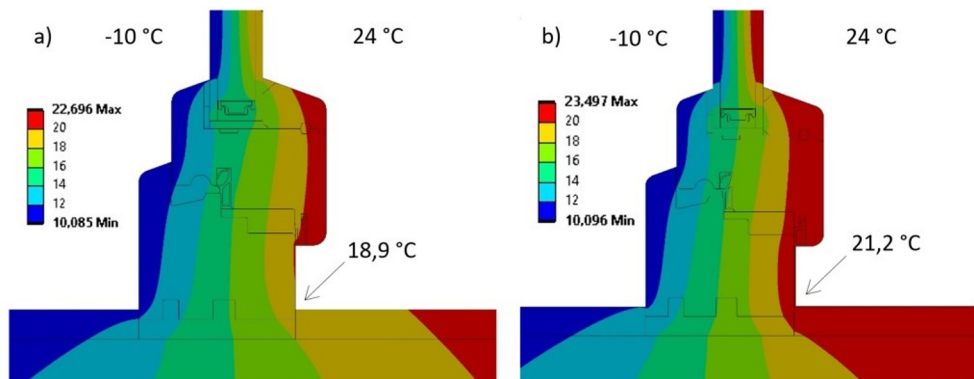
**Fig. 2.** Temperature isotherms in detail of a wooden window: a) without bar, b) without bar with resistance wire 5 W/m, c) with bar on jamb, c) with bar on jamb and resistance wire 5 W/m.

### 3.2 Window jamb – validation

On 14.12.2022, the window jamb of the evaluated window was measured with a thermal imaging camera at an outdoor temperature of 10 °C (see Figure 3). The temperature gradient is 14 °C. Figure 4 shows the results of the thermal behaviour of the jamb model created in a steady-state thermal analysis.



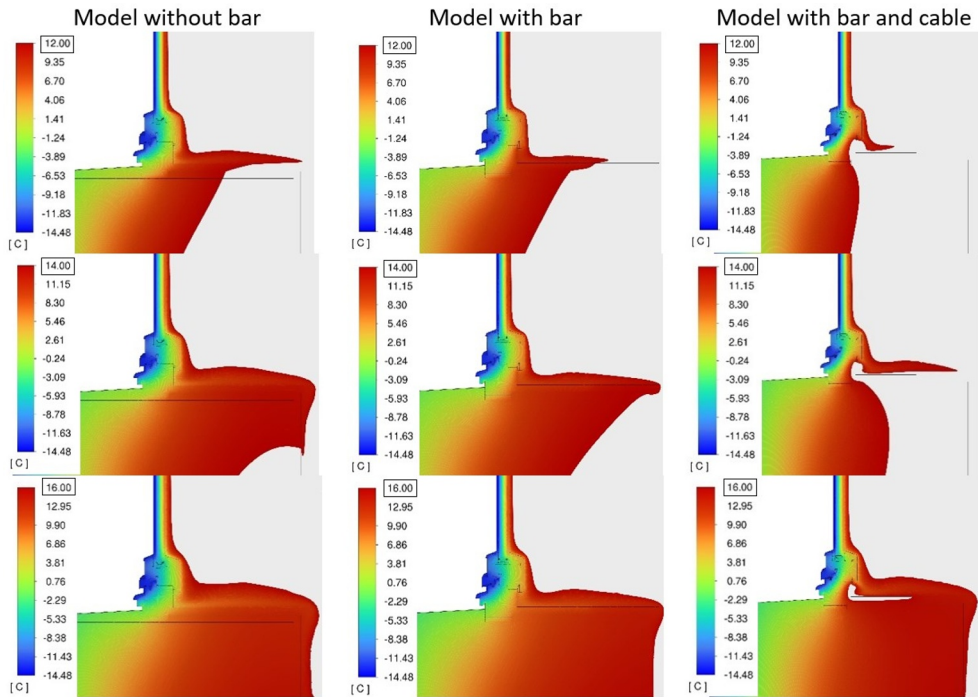
**Fig. 3.** Thermal imaging camera measuring of the bar on the jamb: a) photograph of the subject site, b) thermal image taken on 14.12.2022 with an outdoor temperature of 10 °C, c) thermal image with the attached heating cable taken on 14.12.2022 with an outdoor temperature of 10 °C.



**Fig. 4.** Temperature model of window jamb: a) model without bar, b) model with bar.

### 3.3 Window sill - Flow Analysis

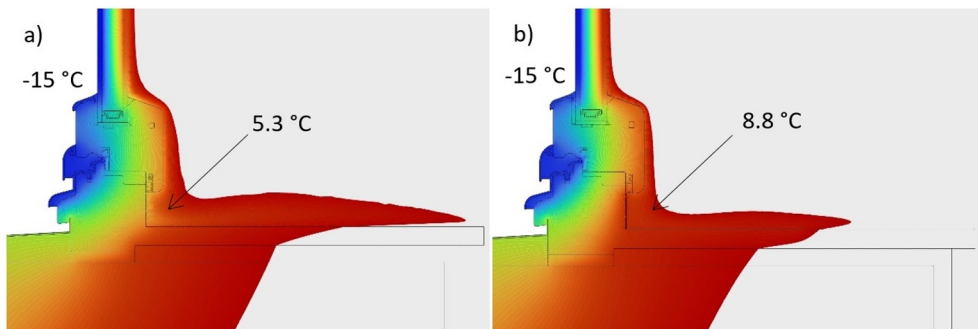
In terms of flow analysis, the detail of the parapet was chosen as the more interesting detail due to the restriction of flow over the parapet. The window detail from the previous assessment was studied; therefore, a wooden window with double glazing was fitted to a solid brick wall. Figure 5 shows a comparison of the temperatures with the maximum specified temperature (isotherm) of 12 °C, 14 °C and 16 °C for the window without modification, with the bar and with the bar and resistance wire.



**Fig. 5.** Flow model divided into columns in detail without treatment, with bar and with bar with heating resistance wire 5 W/m and by rows according to isotherms of 12 °C, 14 °C and 16 °C.

The detail of the window with the bar shows a temperature of 8.8 °C at the connection joint at 12 o'clock compared to the detail without the treatment with a temperature of 5.3 °C. The bar has raised the temperature to 3.5 °C. A heat transfer coefficient of 3 W/m<sup>2</sup>K was found at the sill at the location of the bar. When using a 5 W/m heating resistance wire, the temperature increases to 20.5 °C. This temperature is distributed in detail on the surface of the bar. The heat transfer coefficient has increased to 7.5 W/m<sup>2</sup>K.

Figure 6 shows a more detailed 12°C isotherm for the detail without and with the bar.



**Fig. 6.** Detail of the 12 °C isotherm for the window: a) without bar, b) with bar.

## 4 Discussion

### 4.1 Window jamb – Steady-State Thermal Analysis

As the length increases, the effect of the thickness of the aluminium material becomes evident. As the thickness increases and the length develops, the surface temperature increases. In the case of a placed resistance wire that generates heat, smaller thicknesses of aluminium sheets are more effective.

More interesting than the information about the actual temperature at the connection joint is the monitoring of the isotherm. Especially for the 12 °C isotherm (yellow-orange interface), the change in temperature is visible. The mere presence of the aluminium bar increases the lowest internal surface temperature. This bar takes the temperature from the part of the detail farthest from the window (the hottest part) and passes it on to the coldest part (the connection joint). Therefore, in the case of a detail with placed bar, the maximum temperature of the whole detail is lower.

In the case of using a 5 W/m resistance wire, the higher efficiency of the aluminium bar is seen. The bar removes the heat from the resistance wire and distributes it over its surface, thus ensuring a more even distribution and heating of wider structures. No unnecessary overheating of the local area.

### 4.2 Window jamb – validation

During the validation of the results, the heat transfer coefficient in the model was modified to 7.5 W/m<sup>2</sup>K. After this modification, the results from the thermal imaging camera (Fig. 3b) and the stationary temperature field (Fig. 4b) are consistent. In the image of Fig. 3c, a 10 W/m heating resistance cable was attached to the rail. A temperature of 32.4 °C was measured on the wire, and the model with the cable without the rail shows a cable temperature of 33.6 °C, which is consistent.

### 4.3 Window sill - Flow Analysis

The conductive bar takes heat from the sill area above the radiator and brings it to the window connection joint. The value of the heat transfer coefficient found at the sill corresponds approximately to the standard values used for modelling the stationary temperature field at the walls. The heat transfer coefficient in the case of a resistance wire in combination with a bar indicates that the heating cable promotes airflow at the window connection joint.

The difference in the isotherms is visible in the details (the red waveform bounds the upper limit of the temperature waveform). The model without bar treatment has a more distant isotherm 12 °C compared to the detail with bar in place. This difference is due to the warmer area around the window joints in the case of the placed bar. In all details, the cooler isotherm around the window sill (yellow) is visible in the window without the bar, while the cooler isotherm around the window sill (yellow) is less visible in the window with the bar (see Figure 6 - detail of the 12 °C isotherm). In the case of a window with a heating cable, a grey cavity can be seen at the connection joint (see Fig. 5 - Model with bar and cable). This is caused by a warmer area than the upper limit of the temperature waveforms.

A change in the direction of airflow was observed in the closest proximity to the surface of the window connection joint. If the radiator temperature was lower, the air could cool more significantly and fall back down the surface.

## 5 Conclusions

The work was to remediate the unsatisfactory condition of the connecting joint of a wooden window with double glazing installed on solid brickwork. The detail was investigated in a stationary temperature field at the jamb location and validated by thermal imaging camera. The details of the sill were also studied in terms of airflow (natural convection from the radiator) and the effect of the “air pocket” above the sill on the temperature at the connection joint.

The conductive bar was shown to increase the surface temperature at the connection joint of the window sill and the jamb and distribute the temperature gained over its surface. In the case of using resistance wire in combination with the bar, there was also a noticeable improvement around the critical point. The resistance wire itself is a local remediation. From the results of the flow, it was found that the air flows faster in the case of the resistance wire at the connection joint.

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