

1. Introduction

From 2D thermal simulations of glazed façade parts several derived thermal properties can be defined. Their purpose is to allow corrections on 1D formulas when doing a whole building thermal analysis. Typical derived properties and their interrelation are discussed.

2. Case study data & results

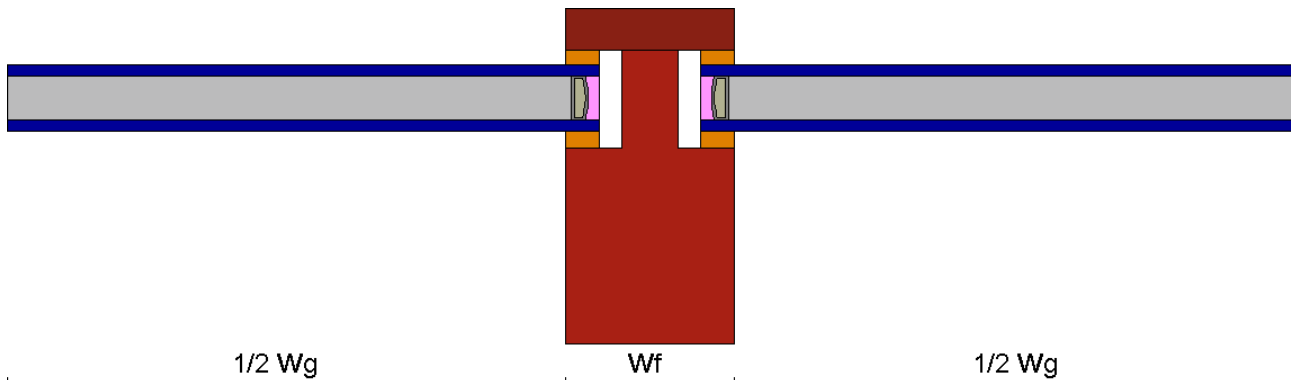


Figure 1: Horizontal section of frame and glazing

Figure 1 shows a horizontal section of a wooden frame with double-glazing between indoors (20 °C) and outdoors (0 °C). The double glazing (4/16/4) has a thermal transmittance $U_g = 1.4 \text{ W/m}^2\text{K}$. An aluminium glazing edge is assumed. The wooden frame is 60 mm width and 120 mm deep. The total width considered is 460 mm. The left and right boundary are considered as adiabatic. The simulation data, according to EN ISO 10077-2:2017, are given in the Bisco data file [section1.bsc](#).

Figure 2 shows the simulation results. The total heat loss is $Q_{2D} = 16.65 \text{ W/m}$. Dividing by the temperature assumed (20 K), the thermal conductance is obtained: $L_{2D} = 0.8325 \text{ W/mK}$. Isotherms and heat flow lines show a clear 2D heat transfer effect, caused both by frame and glazing edges.

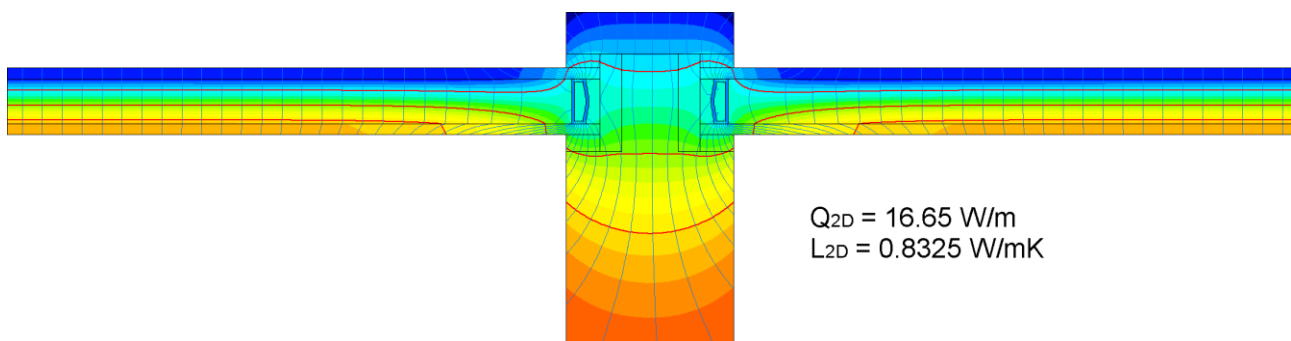


Figure 2. Isotherms (colour increment 1 °C, line increment 5 °C) and heat flow lines (increment 0.2 W/m).

3. The frame thermal transmittance U_f

BISCO data [section1 U frame.bsc](#)

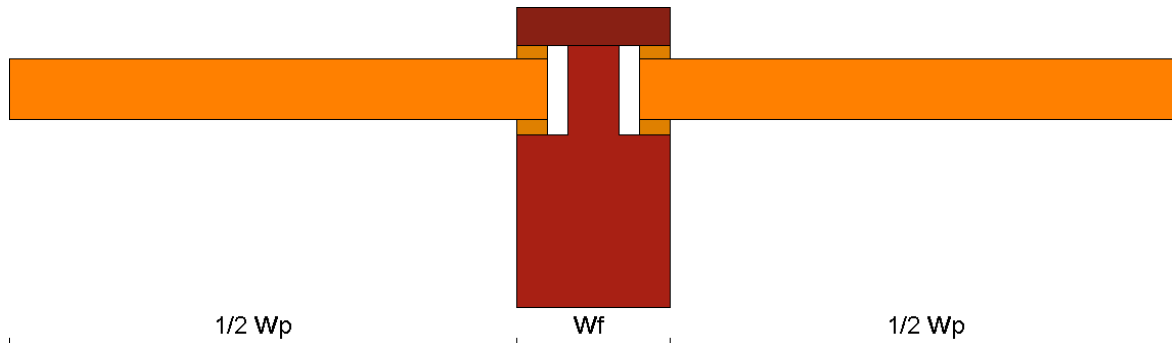


Figure 3. Horizontal section of frame with an insulation panel replacing the glazing

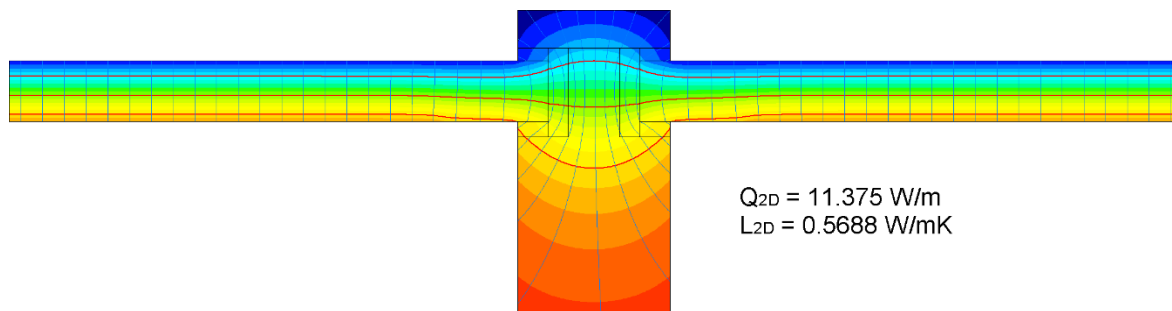


Figure 4. Isotherms (colour increment 1 °C, line increment 5 °C) and heat flow lines (increment 0.2 W/m).

A first derived thermal property is the frame **thermal transmittance U_f** . Among others it is of interest as a thermal quality label for window frame manufacturers. In order to exclude the 2D heat transfer effect caused by the glazing edge, another numerical simulation, with an insulation panel replacing the glazing, is done. According to EN 10077-2 the thermal conductivity of the panel is 0.035 W/mK. The total heat loss is $Q_{2D} = 11.374$ W/m. Dividing by the temperature assumed (20 K), the thermal conductance is obtained: $L_{2D} = 0.5688$ W/mK.

The frame thermal transmittance is defined as:

$$U_f = \frac{L_{2D} - U_p w_p}{w_f} \text{ with } L_{2D} = \frac{Q_{2D}}{\Delta\theta_{ie}} \quad U_f = 1.687 \text{ W/m}^2\text{K}.$$

U_f	[W/m ² K]	frame thermal transmittance
L_{2D}	[W/mK]	thermal conductance of frame and panel
U_p	[W/m ² K]	panel thermal transmittance
w_p	[m]	panel width
w_f	[m]	frame width
Q_{2D}	[W/m ²]	total heat loss
$\Delta\theta_{ie}$	[K]	indoors-outdoors temperature difference

4. The glazing edge linear thermal transmittance ψ_g

BISCO data [section1 psi glazing.bsc](#)

BISCO data [section1 psi glazing half.bsc](#)

A second derived thermal property is the **glazing edge linear thermal transmittance ψ_g** ¹. It is of interest to calculate the thermal transmittance of windows with known frame and glazing thermal transmittances². It is defined as:

$$\psi_g = (L_{2D} - U_f w_f - U_g w_g) / n \quad \psi_g = 0.0855 \text{ W/mK.}$$

ψ_g	[W/mK]	glazing spacer linear thermal transmittance
L_{2D}	[W/mK]	thermal conductance of frame and glazing
U_f	[W/m ² K]	frame thermal transmittance
w_f	[m]	frame width
U_g	[W/m ² K]	glazing thermal transmittance
w_g	[m]	glazing width
n	[-]	number of spacers (1 or 2)

Note: in the Window 'Border U-values' the column 'Enforced U-value' can be used to define the corresponding U_f value (calculated as described in section 0).

5. The node linear thermal transmittance ψ_n

BISCO data [section1 psi node.bsc](#)

A third derived thermal property is the **node linear thermal transmittance ψ_n** . It includes both the thermal effect of the frame and the glass spacer and it is defined as:

$$\psi_n = L_{2D} - U_g w_t \quad \psi_n = 0.188 \text{ W/mK.}$$

ψ_n	[W/mK]	node linear thermal transmittance
L_{2D}	[W/mK]	thermal conductance of frame and glazing
U_g	[W/m ² K]	glazing thermal transmittance
w_t	[m]	total width of frame and glazing ($w_t = w_g + w_f$)

Note: EN ISO 12631³ applies the term ψ_{TJ} (linear thermal transmittance of the joint) in the single assessment method.

¹ See also Physibel Knowledge Base: LINEAR THERMAL TRANSMITTANCE OF A GLAZING SPACER

² See also Physibel Knowledge Base: THERMAL TRANSMITTANCE OF A WINDOW ACCORDING TO EN ISO 10077-1

³ EN 12631:2012 Thermal performance of curtain walling - Calculation of thermal transmittance

6. The frame+edge thermal thermal transmittance U_{fg}

BISCO data [section1 U frame incl glazing edge.bsc](#)

A fourth derived thermal property is the **frame+edge thermal transmittance U_f** . It includes both the thermal effect of the frame and the glass spacer and it is defined as:

$$U_{fg} = \frac{L_{2D} - U_g w_g}{w_f} \text{ with } L_{2D} = \frac{Q_{2D}}{\Delta\theta_{ie}} \quad U_f = 4.54 \text{ W/m}^2\text{K}.$$

U_{fg}	[W/m ² K]	frame+edge thermal transmittance
L_{2D}	[W/mK]	thermal conductance of frame and glazing
U_g	[W/m ² K]	glazing thermal transmittance
w_g	[m]	glazing width
w_f	[m]	frame width

Note: EN ISO 12631⁴ applies the term U_{TJ} (thermal transmittance of the joint) in the single assessment method.

7. Interrelations between the derived thermal properties

Interrelations between the derived thermal properties can be formulated.

The **node linear thermal transmittance ψ_n** can be derived

from the **frame thermal transmittance U_f**
and the **glazing edge linear thermal transmittance ψ_g**

using $\psi_n = (U_f - U_g)w_f + n\psi_g$

The **frame+edge thermal transmittance U_{fg}** can be derived

from the **frame thermal transmittance U_f**
and the **glazing edge linear thermal transmittance ψ_g**

using $U_{fg} = U_f + \frac{n\psi_g}{w_f}$

Further interrelations can be derived easily from the above.

⁴ EN 12631:2012 Thermal performance of curtain walling - Calculation of thermal transmittance

8. Applying the derived thermal properties

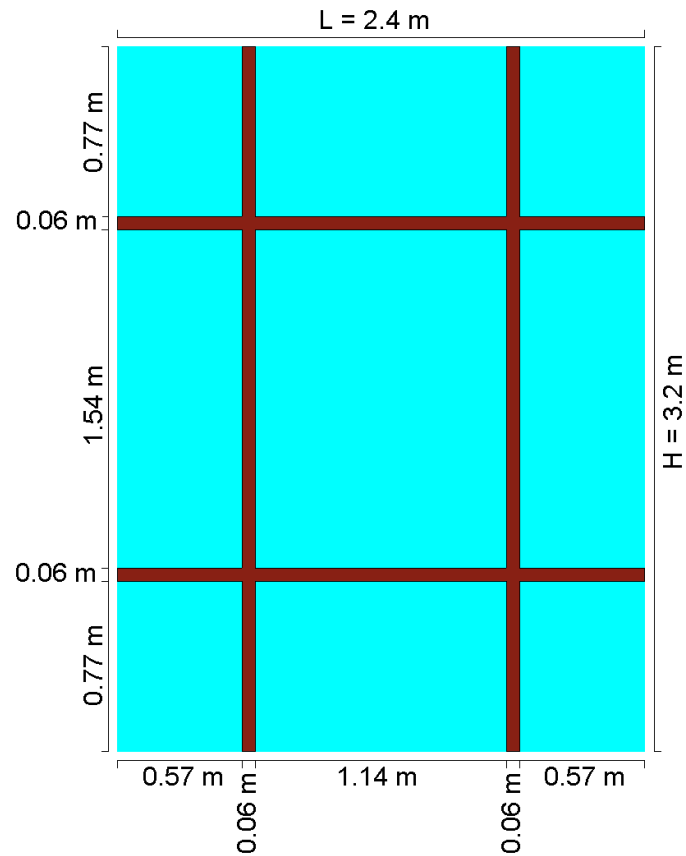


Figure 5. Front view of representative part of a glazed façade.

Figure 5 shows a representative part (borders are symmetry planes) of a glazed façade. The frame section of Figure 1 is assumed. The façade thermal transmittance U_{fac} can be calculated using several methods, applying the derived thermal properties discussed above.

Method 1

$$U_{fac} = \frac{U_g S_g + U_f S_f + \psi_g L_g}{S_t}$$

U_{fac}	[W/m ² K]	façade thermal transmittance
U_g	[W/m ² K]	glazing thermal transmittance
S_g	[m ²]	glazing surface
U_f	[W/m ² K]	frame thermal transmittance
S_f	[m ²]	frame surface
ψ_g	[W/mK]	glazing spacer linear thermal transmittance
L_g	[m]	thermal conductance of frame and glazing

$$U_{fac} = \frac{1.4 \times 7.0224 + 1.687 \times 0.6576 + 0.0855 \times 21.44}{7.68} \quad U_{fac} = 1.663 \text{ W/m}^2\text{K}$$

Method 2

$$U_{fac} = \frac{U_g S_g + U_{fg} S_f}{S_t}$$

U_{fac}	[W/m ² K]	façade thermal transmittance
U_g	[W/m ² K]	glazing thermal transmittance
S_g	[m ²]	glazing surface
U_{fg}	[W/m ² K]	frame+edge thermal transmittance
S_f	[m ²]	frame surface
ψ_g	[W/mK]	glazing spacer linear thermal transmittance
L_g	[m]	thermal conductance of frame and glazing

$$U_{fac} = \frac{1.4 \times 7.0224 + 4.54 \times 0.6576}{7.68} \quad U_{fac} = 1.669 \text{ W/m}^2\text{K}$$

Method 3

$$U_{fac} = U_g + \frac{\psi_n L_n}{S_f}$$

U_{fac}	[W/m ² K]	façade thermal transmittance
U_g	[W/m ² K]	glazing thermal transmittance
ψ_n	[W/mK]	node linear thermal transmittance
L_n	[m]	total node length
S_f	[m ²]	total façade surface

$$U_{fac} = 1.4 + \frac{0.188 \times 11.2}{7.68} \quad U_{fac} = 1.674 \text{ W/m}^2\text{K}$$

9. 3D method

A 3D calculation of the façade (TRISCO file [section1_3D.trc](#)) results in the isotherms shown in Figure 6 and in a thermal transmittance $U_{\text{fac}} = 1.666 \text{ W/m}^2\text{K}$

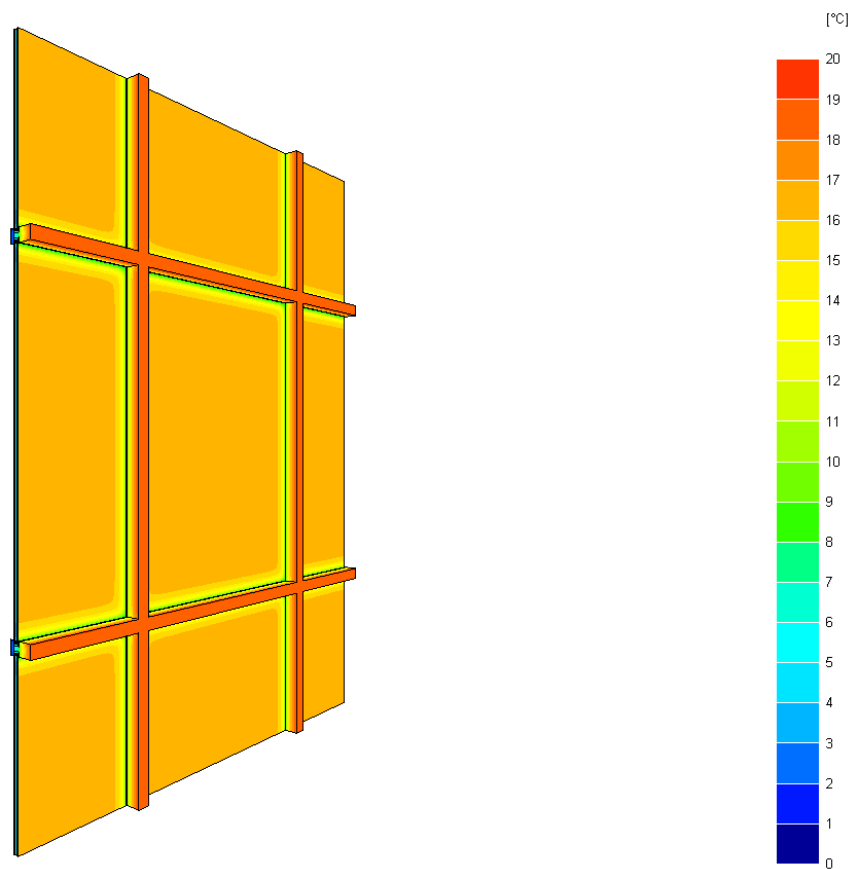


Figure 6. Isotherms (view from the indoors) obtained by a 3D simulation.

10. Discussion

The 3 methods using the derived thermal properties result in almost identical values. Compared to the 3D reference, method 1 results in a too low U-value, due to an underestimation of the glazing edge length (= perimeter of the visual glazing surface).