# GLAZED FACADES:
# DERIVED THERMAL PROPERTIES

## 1. Introduction

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

## 2. Case study data & results

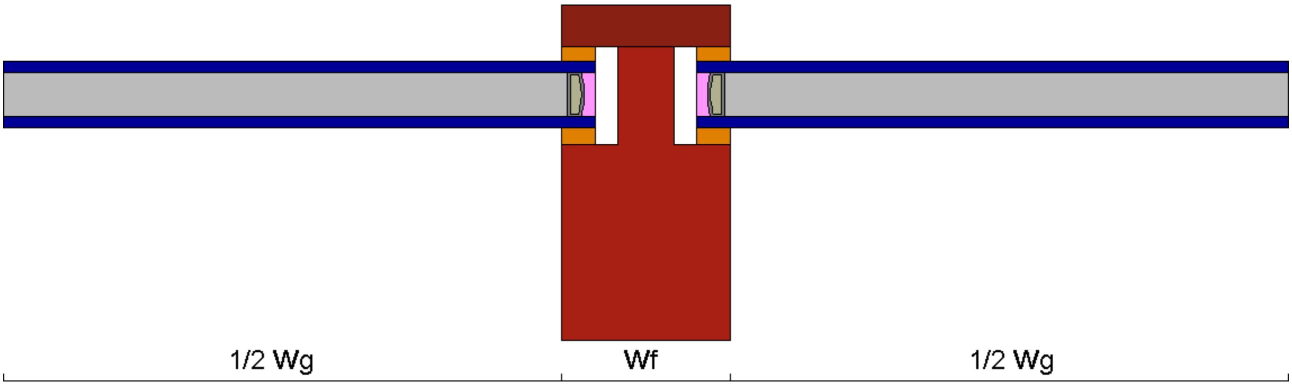


**Figure 1: Horizontal section of frame and glazing**

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 Uf = 1.4 W/m2K. 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.](section1.bsc)

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

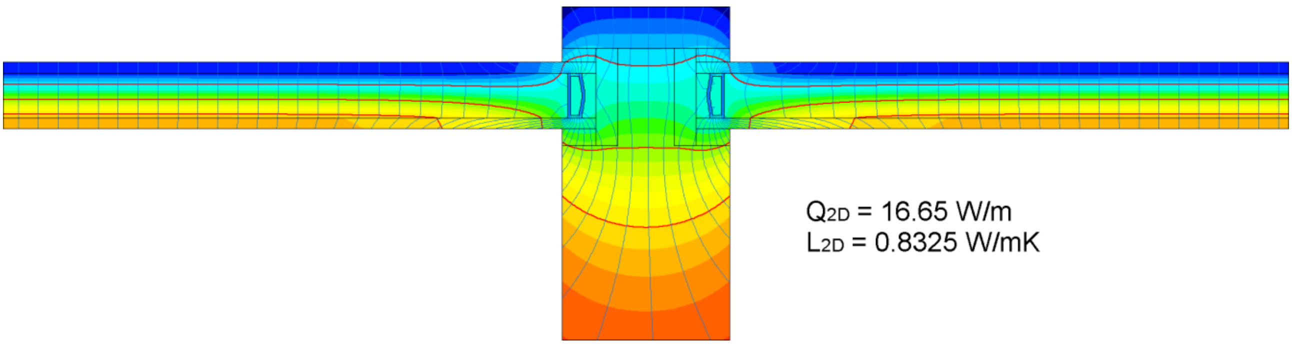


**Figure 2. Isotherms (colour increment 1 °C, line increment 5 °C) and heat flow lines (increment 0.2 W/m).**

## 3. The frame thermal transmittance Uf

BISCO data section1_U_frame.bsc

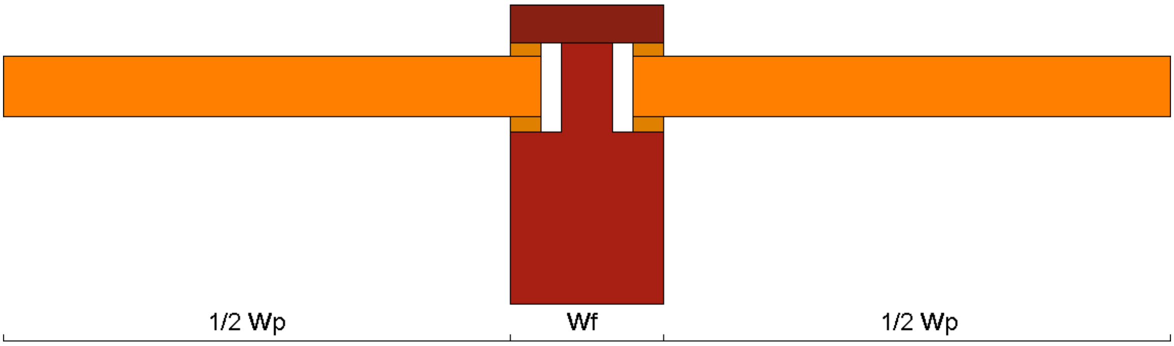


Figure 3. Horizontal section of frame with an insulation panel replacing the glazing

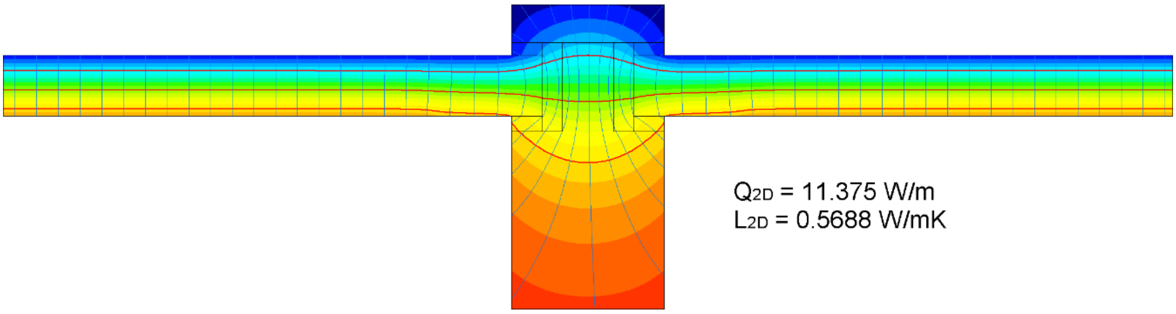


Figure 4. Isotherms (colour increment 1 °C, line increment 5 °C) and heat flow lines (increment 0.2 W/m).

A first derived thermal property is the frame **thermal transmittance Uf**. 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 Q2D = 11.374 W/m. Dividing by the temperature assumed (20 K), the thermal conductance is obtained: L2D = 0.5688 W/mK.
The frame thermal transmittance is defined as:

$$U_f = \frac{L_{2D} - U_p w_p}{w_f} \quad \text{with} \quad L_{2D} = \frac{Q_{2D}}{\Delta\theta_{ie}}$$

$U_f$ = 1.687 W/m²K.

| | | |
|---|---|---|
| $U_f$ | [W/m²K] | frame thermal transmittance |
| $L_{2D}$ | [W/mK] | thermal conductance of frame and panel |
| $U_p$ | [W/m²K] | panel thermal transmittance |
| $w_p$ | [m] | panel width |
| $w_f$ | [m] | frame width |
| $Q_{2D}$ | [W/m²] | total heat loss |
| $\Delta\theta_{ie}$ | [K] | indoors-outdoors temperature difference |

## 4. The glazing edge linear thermal transmittance $\psi_g$

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 $\psi_g$**[1]. It is of interest to calculate the thermal transmittance of windows with known frame and glazing thermal transmittances[2]. It is defined as:

$$\psi_g = (L_{2D} - U_f w_f - U_g w_g)/n$$

$\psi_g$ = 0.0855 W/mK.

| | | |
|---|---|---|
| $\psi_g$ | [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 Uf value (calculated as described in section 3).

## 5. The node linear thermal transmittance $\psi_n$

BISCO data section1_psi_node.bsc

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

$$\psi_n = L_{2D} - U_g w_t$$

$\psi_n$ = 0.188 W/mK.

| | | |
|---|---|---|
| $\psi_n$ | [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 12631[3] applies the term $\psi_{TJ}$ (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:

$$U_{fg} = \frac{L_{2D} - U_g w_g}{w_f} \quad \text{with} \quad L_{2D} = \frac{Q_{2D}}{\Delta\theta_{ie}}$$

$U_f$ = 4.54 W/m²K.

| | | |
|---|---|---|
| $U_{fg}$ | [W/m²K] | frame+edge thermal transmittance |
| $L_{2D}$ | [W/mK] | thermal conductance of frame and glazing |
| $U_g$ | [W/m²K] | glazing thermal transmittance |
| $w_g$ | [m] | glazing width |
| $w_f$ | [m] | frame width |

Note: EN ISO 12631[4] 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 $\psi_n$ can be derived
from the frame thermal transmittance $U_f$
and the glazing edge linear thermal transmittance $\psi_g$

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 $\psi_g$

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

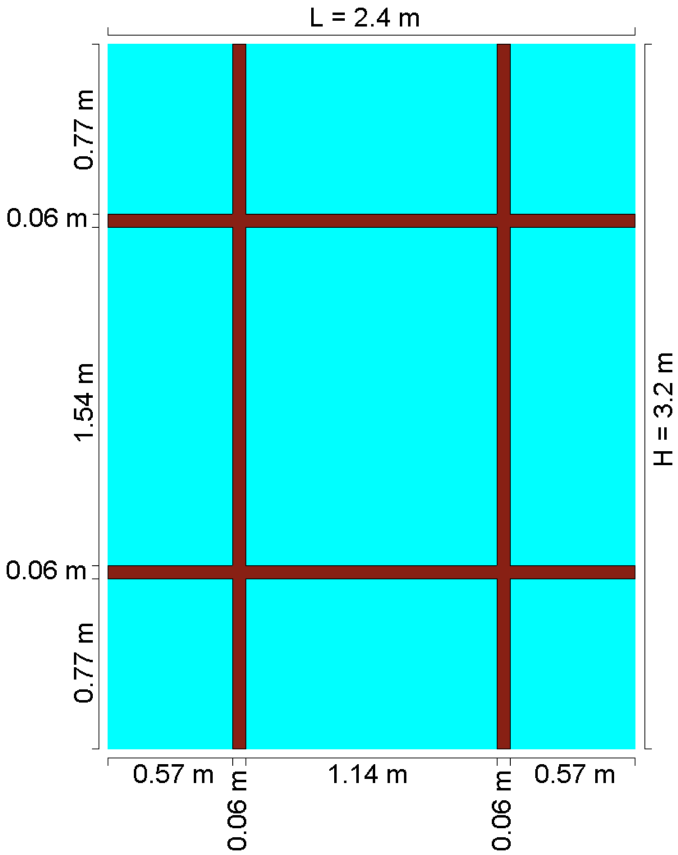


Figure 5. Front view of representative part of a glazed façade.

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/m²K] | façade thermal transmittance |
| $U_g$ | [W/m²K] | glazing thermal transmittance |
| $S_g$ | [m²] | glazing surface |
| $U_f$ | [W/m²K] | frame thermal transmittance |
| $S_f$ | [m²] | frame surface |
| $\psi_g$ | [W/mK] | glazing spacer linear thermal transmittance |
| $L_g$ | [m] | thermal conductance of frame and glazing |

$$U_{fac} = \frac{1.4 \times 7.0224 + 1.687 \times 0.6576 + 0.0855 \times 21.44}{7.68}$$

$U_{fac}$ = 1.663 W/m²K

## Method 2

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

| | | |
|---|---|---|
| $U_{fac}$ | [W/m²K] | façade thermal transmittance |
| $U_g$ | [W/m²K] | glazing thermal transmittance |
| $S_g$ | [m²] | glazing surface |
| $U_{fg}$ | [W/m²K] | frame+edge thermal transmittance |
| $S_f$ | [m²] | frame surface |
| $\psi_g$ | [W/mK] | glazing spacer linear thermal transmittance |
| $L_g$ | [m] | thermal conductance of frame and glazing |

$$U_{fac} = \frac{1.4 \times 7.0224 + 4.54 \times 0.6576}{7.68}$$

$U_{fac}$ = 1.669 W/m²K

## Method 3

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

| | | |
|---|---|---|
| $U_{fac}$ | [W/m²K] | façade thermal transmittance |
| $U_g$ | [W/m²K] | glazing thermal transmittance |
| $\psi_n$ | [W/mK] | node linear thermal transmittance |
| $L_n$ | [m] | total node length |
| $S_f$ | [m²] | total façade surface |

$$U_{fac} = 1.4 + \frac{0.188 \times 11.2}{7.68}$$

$U_{fac}$ = 1.674 W/m²K

## 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 $U_{fac}$ = 1.666 W/m$^2$K

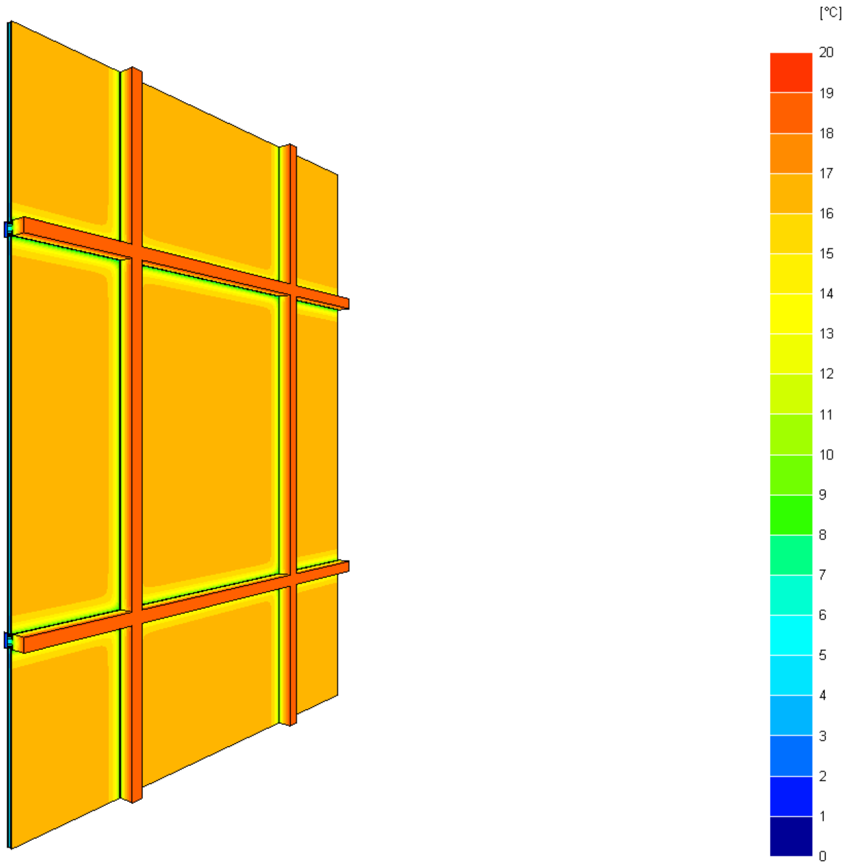


Figure 6. Isotherms (view from the indoors) obtained by a 3D simulation.

## 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).