THERMAL TRANSMITTANCE CALCULATION OF A VERANDA

physibel

1. Introduction

A case study shows how the thermal transmittance of a veranda can be calculated taking into effect the 2D thermal heat loss effects through frames and glazing edges. A methodology compliant to the standards EN ISO 6946 and EN ISO 10077-2 for use with the Physibel program BISCO is explained and applied.

2. Methodology

The target of the standard EN ISO 10077-2 is to derive the thermal transmittance of a frame using a numerical method. It is an alternative for the hot box measurement (EN 12412–2). These standards assume:
- the frame is in vertical position, causing a horizontal heat flow direction,
- the glazing is replaced by an insulation panel,
- the frame isn't a corner frame (as e.g. the frame S3 mentioned further is).
The standards allow the frame manufacturer to declare the frame thermal performance.
In the case of the veranda the manufacturer wants to declare the thermal performance of the total construction (U_{tot}-value) including frames, glazing, glazing edges and possible junctions to walls and roofs. Because of the assumptions mentioned, the EN ISO 10077-2 (and the hot box measurement) fails for this purpose.

The standards EN ISO 6946 (Building components and building elements - Thermal resistance and thermal transmittance - Calculation) and EN 673 (Glass in Building – Determination of thermal transmittance (U value) - Calculation method) contain the missing links for a methodology to determine the thermal performance of the total veranda.

In the determination of the total thermal performance, 4 steps can be distinguished.

Step 1 concerns the glazing thermal transmittance (U_g-value) determination according to EN 673. For each slope a U_g-value needs to be determined. This step can be done using a spreadsheet. Alternatively the values could be given by the glazing manufacturer.

Step 2 concerns the 2D heat transmission simulation through each relevant section of the veranda. It results in a heat loss Q_{2D} for each section. This step can be done using BISCO. 2 methods are proposed. A first one (method A) uses the EN ISO 10077-2 'single equivalent thermal conductivity method' for cavities, a second one (method B) uses the EN ISO 10077-2 'radiosity method' for cavities (advanced infra-red calculation).

Step 3 concerns the "derived thermal properties". In this case linear thermal transmittances (ψ-values) are derived from the heat loss Q_{2D} for each section. Also this step can be done using BISCO; alternatively a spreadsheet could be used.

Step 4 concerns the thermal transmittance of the total construction (U_{tot}-value). A spreadsheet is used to derive the U_{tot}-value from the U_g-values (step 1), the ψ-values (step 3) and the veranda dimensions.

Step 1. Glazing simulation.

The glazing thermal transmittance is calculated according to EN 673:
- in vertical position,
- in 45 ° sloped position,
- in horizontal position.

The U-value of the glazing in his real positions is derived by linear interpolation.
From the glazing U-value an equivalent cavity thermal conductivity λ_{cav-eq} can be derived. In the BISCO simulations (step 2) the cavity will be defined as an EQUIMAT with the value λ_{cav-eq}.
The spreadsheets U_double_glazing_EN673.xlsx and U_triple_glazing_EN673.xlsx can be used.

Step 2. Method A.

The 2D heat transmission is calculated using BISCO with the following rules.

- Use material λ-values from EN ISO 10077-2 and EN ISO 10456 from the Colour database.
- For the outdoor
  use BC_SIMPL with θ_e = 0 °C, h_e = 25 W/m^{2}K (Colour 170);
  this is compliant with EN ISO 10077-2 and EN ISO 6946.
- For the indoor bordering vertical glazings and frames (**horizontal** heat transfer)
  use BC_SIMPL with θ_i= 20 °C, **h_i= 7.7 W/m^{2}K** (Colour 174);
  this is compliant with EN ISO 10077-2 and EN ISO 6946.
  Surfaces with a slope between 60° and 90° are considered as vertical (EN ISO 6946).
- For the indoor bordering horizontal glazings and frames (**upwards** heat transfer)
  use BC_SIMPL with θ_i= 20 °C, **h_i= 10 W/m^{2}K** (Colour 190);
  this is compliant with EN ISO 6946.
  Surfaces with a slope < 60° are considered as horizontal (EN ISO 6946).
- **Don't use indoor reduced surface heat transfer zones (h_i = 5 W/m^{2}K**, Colour 182).
  Indeed clear standard rules about the exact location lack. The rules of EN ISO 10077-2 concern vertical frames in a wall (not in a corner) only and cannot be extrapolated in an unambiguous way.
- For non-ventilated frame cavities in which **horizontal** heat transfer occurs
  use EQUIMAT with subtype 'Cavity' and Standard 'EN10077' or 'EN6946';
  this is compliant with EN ISO 10077-2 and EN ISO 6946.

Colours

Col.		**Type**	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [-/-]	λ [W/mK]	ε [-]	Standard
214		EQUIMAT	CAVITY	HOR	Y	cavity (CEN)	0.90 / 0.90	0.137		EN10077

- For non-ventilated cavities in which **upwards** heat transfer occurs
  use EQUIMAT with Subtype 'Cavity', Standard 'EN 6946' and Physical flow direction 'UP' which is compliant with EN ISO 6946 (compliance with EN ISO 10077-2 is not possible as this standards only assume horizontal heat transfer).

Colours

Col.		Type	Subtype	**Physical flow dir.**	Geometrical flow dir.	Name	ε1 / ε2 [-/-]	λ [W/mK]	ε [-]	Standard
214		EQUIMAT	CAVITY	UP	Y	cavity (CEN)	0.90 / 0.90	0.157		EN6946

- For slightly ventilated cavities in which **horizontal** heat transfer occurs
  use EQUIMAT with Subtype 'Cavity_E' and Standard 'EN10077; this is compliant with EN ISO 10077-2. (slightly ventilated cavities are not defined in EN ISO 6946)

Colours

Col.		Type	**Subtype**	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [-/-]	λ [W/mK]	ε [-]	Standard
214		EQUIMAT	CAVITY_E	HOR	X	cavity (CEN)	0.90 / 0.90	0.111		EN10077

- For slightly ventilated cavities in which **upwards** heat transfer occurs
  EN ISO 10077-2 does not define upward heat flow and EN ISO 6946 does not define slightly ventilated cavities. It is thus recommended to threat these cavities as boundary conditions (conservative assumption).

- In Calculation Parameters
  switch on "Recalculate before each iteration cycle",
  switch on "Use solution temperatures".

Step 2. Method B.

The 2D heat transmission is calculated using BISCO with the following rules.
- Use material λ-values and ε-values from EN ISO 10077-2 and EN ISO 10456.

- For the outdoor
  use BC_SIMPL with θ_e = 0 °C, h_e = 25 W/m²K (Colour 170);
  this is compliant with EN ISO 10077-2 and EN ISO 6946.

- For the indoor bordering vertical glazings and frames (**horizontal** heat transfer)
  use BC_SKY with $\theta_{iair} = \theta_{irad}$ = 20 °C, **h_{ic}= 2.5 W/m²K** (Colour 181);
  this is compliant with EN ISO 6946 annex C.1.
  Surfaces with a slope between 60 ° and 90 ° are considered as vertical (EN ISO 6946).

- For the indoor bordering horizontal glazings and frames (**upwards** heat transfer)
  use BC_SKY with $\theta_{iair} = \theta_{irad}$ = 20 °C, **h_{ic}= 5.0 W/m²K** (Colour 184);
  this is compliant with EN ISO 6946 annex C.1.
  Surfaces with a slope < 60 ° are considered as horizontal (EN ISO 6946).

  The use of BC_SKY is a physically correct alternative for the reduced indoor surface heat transfer (h_i = 5 W/m²K)[1].

- For non-ventilated cavities in which **horizontal** heat transfer occurs
  use TRANSMAT with Subtype 'Cavity' and Standard 'EN10077'; this is compliant with EN ISO 10077-2.

Colours

Col.		**Type**	Subtype	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [-/-]	λ [W/mK]	ε [-]	Standard
214		TRANSMAT	CAVITY	HOR	DIR	cavity (CEN)		0.025		EN10077

- For non-ventilated cavities in which **upwards** heat transfer occurs
  EN ISO 10077-2 does not define upward heat flow and EN ISO 6946 does not explicitly define advance radiation in cavities (type TRANSMAT).

[1] See Knowledge Base document: Experimental validation of internal surface heat transfer

Therefore, use Type TRANSMAT with Subtype ‘Cavity’, Standard ‘NIHIL’ and Physical flow direction ‘UP’. In this way the convective heat transfer is compliant with EN ISO 6946, and the detailed radiative heat transfer is compliant with the radiosity method (EN ISO 10077-2).

Colours

Col.		Type	**Subtype**	Physical flow dir.	Geometrical flow dir.	Name	ε1 / ε2 [-/-]	λ [W/mK]	ε [-]	Standard
214		TRANSMAT	CAVITY	UP	DIR	cavity (CEN)		0.025		NIHIL

- For slightly ventilated cavities in contact with outdoor,
  use BC_SIMPL with Subtype HE_CAV_E and Standard ‘EN 10077’ with θ_e = 0 °C, h_e = 3.333 W/m^{2}K (Colour 251); this is compliant with EN ISO 10077-2.

- For slightly ventilated cavities in contact with indoor,
  use BC_SIMPL with Subtype HI_CAV_E and Standard ‘EN 10077’ with θ_e = 20 °C, h_e = 3.333 W/m^{2}K (Colour 249); this is compliant with EN ISO 10077-2.

- In Calculation Parameters
  switch on “Recalculate before each iteration cycle”,
  switch on “Use solution temperatures”.

Step 3. “Derived thermal properties”: ψ-values.

This step is explained in the case study below.

Step 4. Thermal transmittance of the total construction: U_{tot}-value.

This step is explained in the case study below.

3. Case study data

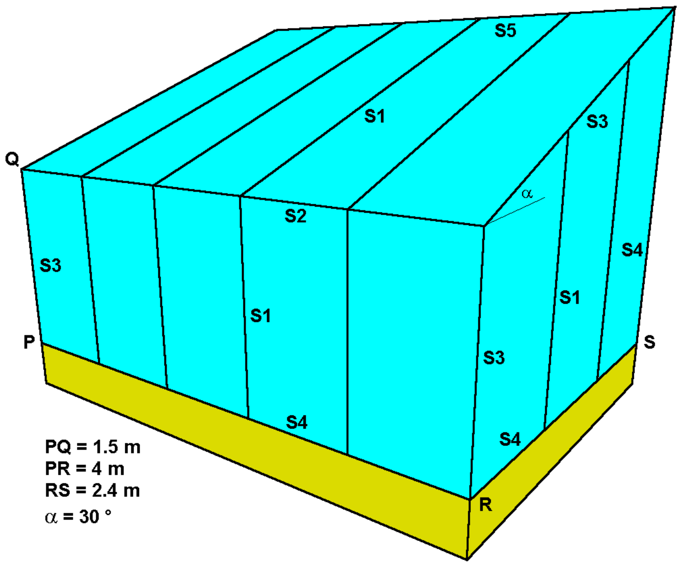

Figure 1. Veranda geometry and indication of sections

A veranda connected to a building (Figure 1) is considered. 5 relevant frame sections occur (Figure 2). As the sections S1 and S3 occur both in wall and roof, 7 sections need to be simulated. Material properties according to EN ISO 10077-2 are assumed. A double glazing 4/16/4 is assumed with a argon filled cavity and a low emissivity coating (ε = 0.04) on one of the panes. The mean thermal transmittance of the entire glazed part needs to be calculated. Adiabatic junctions to the rest of the building are assumed.

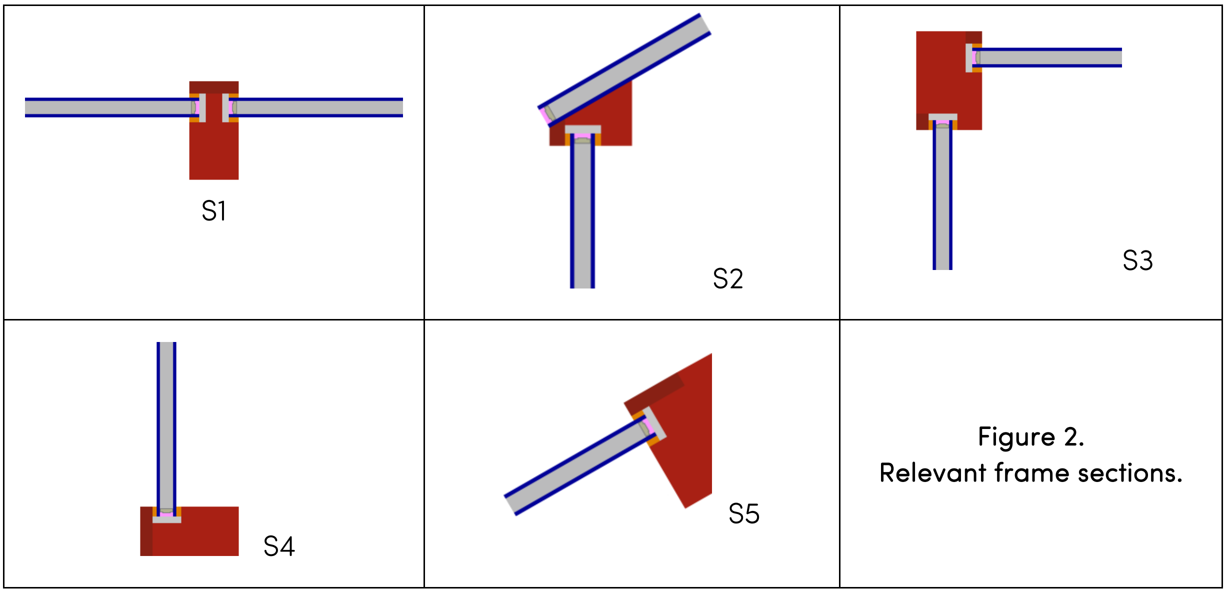

Figure 2.
Relevant frame sections.

Case study. Step 1. Glazing U-value calculation

The spreadsheet U_double_glazing_EN673.xlsx is used to derive the following values
- vertical glazing U_g = 1.10 W/m²K λ_{cav-eq} = 0.02181 W/mK
- 45 ° sloped glazing U_g = 1.52 W/m²K λ_{cav-eq} = 0.03137 W/mK
- horizontal glazing U_g = 1.74 W/m²K λ_{cav-eq} = 0.03749 W/mK

By linear interpolation:
- 30 ° sloped glazing U_g = 1.59 W/m²K λ_{cav-eq} = 0.03341 W/mK

Case study. Step 2. 2D heat transmission simulation

The BISCO simulation data for the 7 relevant sections according are listed in Table 1 (method A) and Table 2 (method B). The rules as explained above are applied in these data.

Case study. Steps 3 & 4. ψ-values and U_{tot}-value

The total thermal transmittance of the construction is calculated using the following formula.

$$U_{tot} = \frac{U_{gw}S_w + U_{gr}S_r + \psi_{1w}L_{1w} + \psi_{1r}L_{1r} + \psi_2 L_2 + \psi_{3w}L_{3w} + \psi_{3r}L_{3r} + \psi_4 L_4 + \psi_5 L_5}{S_{tot}}$$

with

U_{tot}	U-value of total envelope
U_{gx}	U-value of glazing i (x=w for vertical glazing, x=r for sloped glazing)
S_w	total vertical area (of wall), measured in external glazing surface
S_r	total sloped area (of roof), measured in external glazing surface
ψ_i	linear thermal transmittance of section i
L_i	length of section i
S_{tot}	total envelope area.

The section linear thermal transmittances ψ represent the supplementary heat loss compared to a veranda that is completely glazed (with a glazing without edges).
An unambiguous area definition is required: the external glazing area is used (Figure 3, Figure 4).

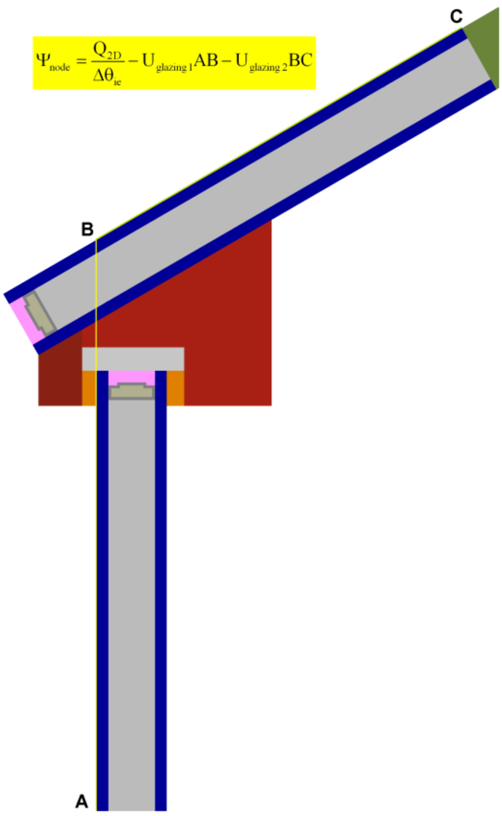

Figure 3. ψ-definition for section 2

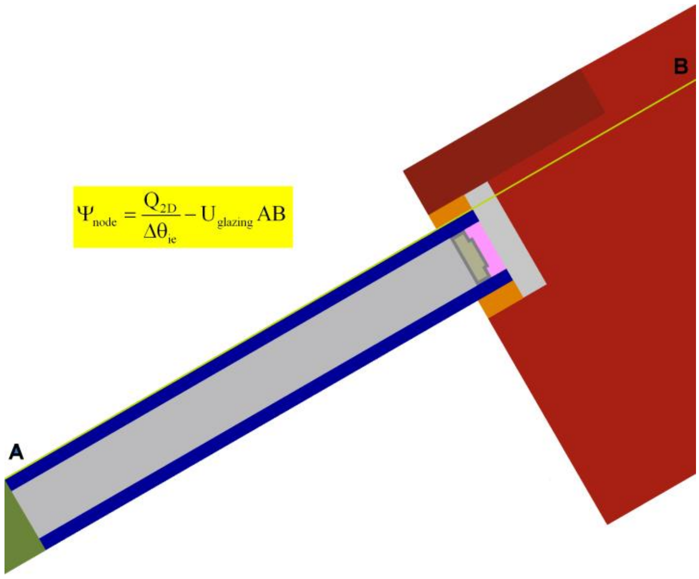

Figure 4. ψ-definition for section 5

Table 1 contains the results using method A.
Table 2 contains the results using method B.
The calculations were made using the spreadsheet Veranda_U.xlsx.

						xlsx data / BISCO data
S_w [m^2]	16.5		U_{gw} [W/m^{2}K]	1.10		U_double_glazing_EN673.xlsx
S_r [m^2]	11.1		U_{gr} [W/m2K]	1.59		U_double_glazing_EN673.xlsx
L_{1w} [m]	14.8		ψ_{1w} [W/mK]	0.266		section1_wall_A.bsc
L_{1r} [m]	11.1		ψ_{1r} [W/mK]	0.250		section1_roof_A.bsc
L_2 [m]	4.0		ψ_2 [W/mK]	0.110		section2_A.bsc
L_{3w} [m]	3.0		ψ_{3w} [W/mK]	0.204		section3_wall_A.bsc
L_{3r} [m]	5.5		ψ_{3r} [W/mK]	0.177		section3_roof_A.bsc
L_4 [m]	14.6		ψ_4 [W/mK]	0.141		section4_A.bsc
L_5 [m]	4.0		ψ_5 [W/mK]	0.085		section5_A.bsc
S_{tot} [m^2]	27.6		U_{tot} [W/m^{2}K]	1.70		

Table 1. U_{tot} calculation using method 1 (Veranda_U.xlsx Method A)

						xlsx data / BISCO data
S_w [m^2]	16.5		U_{gw} [W/m^2K]	1.10		U_double_glazing_EN673.xlsx
S_r [m^2]	11.1		U_{gr} [W/m^2K]	1.59		U_double_glazing_EN673.xlsx
L_{1w} [m]	14.8		ψ_{1w} [W/mK]	0.226		section1_wall_B.bsc
L_{1r} [m]	11.1		ψ_{1r} [W/mK]	0.220		section1_roof_B.bsc
L_2 [m]	4.0		ψ_2 [W/mK]	0.089		section2_B.bsc
L_{3w} [m]	3.0		ψ_{3w} [W/mK]	0.150		section3_wall_B.bsc
L_{3r} [m]	5.5		ψ_{3r} [W/mK]	0.125		section3_roof_B.bsc
L_4 [m]	14.6		ψ_4 [W/mK]	0.119		section4_B.bsc
L_5 [m]	4.0		ψ_5 [W/mK]	0.067		section5_B.bsc
S_{tot} [m^2]	**27.6**		U_{tot} [W/m^2K]	**1.63**		

Table 2. U_{tot} calculation using method 2 (Veranda_U.xlsx sheet Method B)