FLOOR THERMAL TRANSMITTANCE AND FOUNDATION LINEAR TRANSMITTANCE (EN ISO 13370 and EN ISO 10211)

Content

1. Introduction

To calculate the <u>thermal transmittance of a floor on ground U_g</u>, EN ISO 13370 allows several methods:

1. a 3D numerical method as used for thermal bridges according to EN ISO 10211
2. a 2D numerical method, using a floor that is infinitely long and has a width equal to the characteristic dimension of the floor.
3. a simplified method as described in the standard.

To calculate the <u>linear thermal transmittance of a wall/floor junction ψ_g</u> only the 2D and the 3D numerical methods are applicable.

A case study shows the use of these methods.

2. Case study data

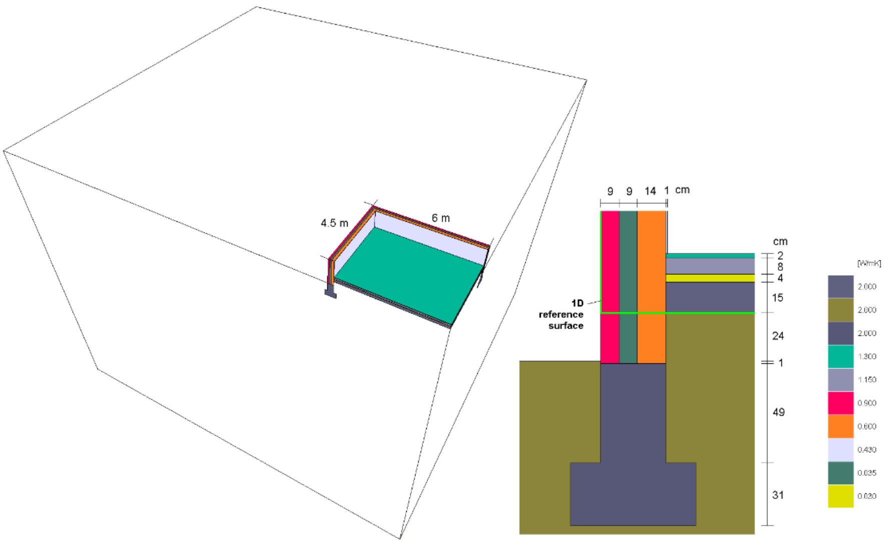


Figure 1: case study data

A building with external dimensions length = 12 m and width = 9 m is considered. Because of symmetry it is sufficient to consider a quarter of the building. Figure 1 shows the geometrical data and the thermal conductivities of the materials. The boundary conditions are:

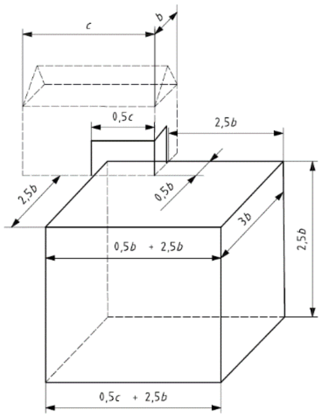
- outdoors: temperature θ_e = 0 °C, surface heat transfer coefficient = 25 W/m^{2}K,

- indoors: temperature θ_i = 20 °C, wall surface heat transfer coefficient = 7.7 W/m^{2}K, floor surface heat transfer coefficient = 5.9 W/m^{2}K.

The calculation of the foundation linear thermal transmittance will be based on the 1D reference surface specified in Figure 1 (**external dimensions**).

3. 3D numerical method

TRISCO data foundation_psi_3D_TR0.trc ; foundation_psi_3D_TR1.trc



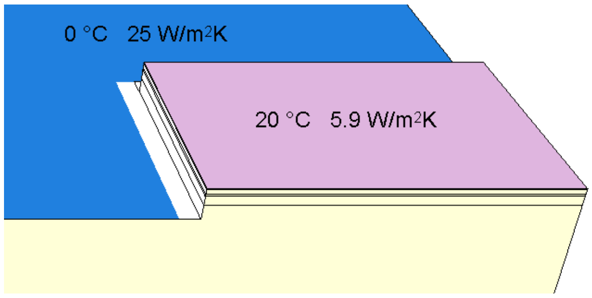


Figure 2 (left): 3D geometrical modelling rules according to EN ISO 10211
Figure 3 (right) : Boundary conditions used to derive the thermal transmittance U_g

Thermal transmittance of the floor U_g.

Figure 2 shows the 3D geometrical modelling rules according to EN ISO 10211. To derive the thermal transmittance of the floor U_g, the wall is replaced by an adiabatic condition and the foundation is replaced by ground as shown in Figure 3 and simulated in 3D (TRISCO data foundation_psi_3D_TR0.trc). The U_g-value is derived directly from the TRISCO results (Table 2) and also in the spreadsheet shown in Table 1 (floor_U_psi_values.xlsx) using the formulas listed in that table.

Linear thermal transmittance of the wall/floor junction ψ_g.

To derive the linear thermal transmittance of the wall/floor junction ψ_g, a second simulation of the complete model is required (TRISCO data foundation_psi_3D_TR1.trc).

The linear thermal transmittance ψ_g can be derived in TRISCO by dividing the 3D surplus thermal transmittance ($dL = L_{3D} - U_w S_w - U_g S_g$ =0.581 W/K) by the length of the thermal bridge (l + b = 10.5 m): ψ_g = 0.055 W/mK (Table 3). The thermal transmittance U_g obtained above is defined in TRISCO as an enforced U-value. The ψ_g-value is derived also in the spreadsheet shown in Table 1 (spreadsheet floor_U_psi_values.xlsx).

Figure 4 and Figure 5 show the graphic results (isotherms) of both simulations.

Complete thermal transmittance of the floor U'_g.

It is possible to derive the complete thermal transmittance of the floor U'_g that includes the thermal bridge effects, using one single simulation (TRISCO data foundation_psi_3D_TR1.trc, Table 3). The U'_g-value is derived directly in TRISCO and also in the spreadsheet shown in Table 1.

3D method	Q_{3D} [W]	$\Delta\theta_{ie}$ [K]	L_{3D} [W/K]	l/2 [m]	b/2 [m]	S_g [m²]	U_g [W/m²K]
foundation_psi_3D_TR0.trc	159,8	20,0	7,9900	6,000	4,500	27,000	**0,296**

	Q_{3D} [W]	$\Delta\theta_{ie}$ [K]	L_{3D} [W/K]	l/2 [m]	b/2 [m]	h [m]	S_g [m²]	U_w [W/m²K]	S_w [m²]	U'_g [W/m²K]	ψ_g [W/mK]
foundation_psi_3D_TR1.trc	258,9	20,0	12,9450	6,000	4,500	1,290	27,000	0,323	13,545	**0,317**	**0,055**

$$L_{3D} = \frac{Q_{3D}}{\Delta\theta_{ie}} \qquad U_g = \frac{L_{3D}}{S_g} \qquad U'_g = \frac{L_{3D} - U_w S_w}{S_g} \qquad \Psi_g = \frac{L_{3D} - U_w S_w - U_g S_g}{(l + b)}$$

Table 1. Derivation of U_g, ψ_g and U'_g.

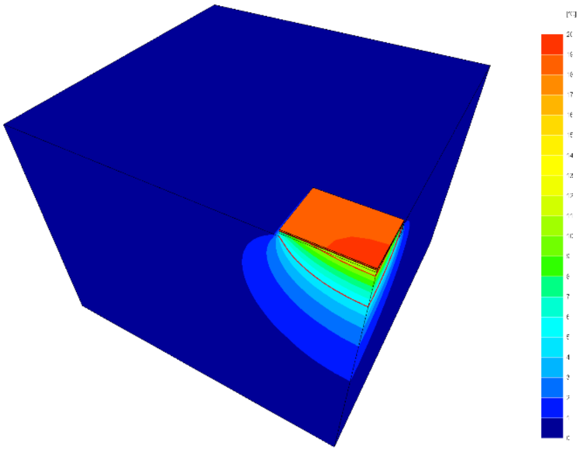


Figure 4
3D simulation without considering the junction: isotherms

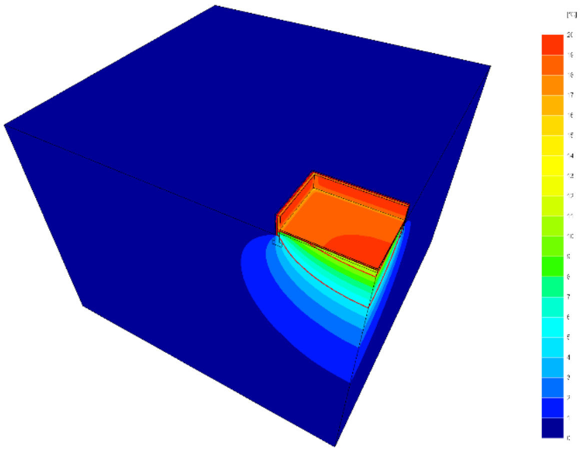


Figure 5
3D simulation for the complete 3D model: isotherms

```
Ufloor = (Q/(ti-te))/A1 = 0.296 W/(m².K)
  Q = 159.805 W
  ti = 20.00°C
  te = 0.00°C
  A1 = 27 m²
       Xmin=33 Xmax=78 Ymin=33 Ymax=78 Zmin=79 Zmax=79
```

Table 2. Derivation U_g in TRISCO (text output foundation_psi_3D_TR0.trc)

```
2D/3D surplus thermal transmittance
dL = Q/(ti-te) - U1*A1 - U2*A2 - U3*A3 = 0.581 W/K
  Q = 258.903 W
  ti = 20.00°C
  te = 0.00°C
  U1 = 0.296 W/(m².K)
       Xmin=78 Xmax=78 Ymin=78 Ymax=78 Zmin=0 Zmax=109
  A1 = 27 m²
       Xmin=33 Xmax=78 Ymin=33 Ymax=78 Zmin=79 Zmax=79
  U2 = 0.323 W/(m².K)
       Xmin=0 Xmax=78 Ymin=78 Ymax=78 Zmin=109 Zmax=109
  A2 = 7.74001 m²
       Xmin=33 Xmax=33 Ymin=33 Ymax=78 Zmin=79 Zmax=109
  U3 = 0.323 W/(m².K)
       Xmin=78 Xmax=78 Ymin=0 Ymax=78 Zmin=109 Zmax=109
  A3 = 5.80501 m²
       Xmin=33 Xmax=78 Ymin=33 Ymax=33 Zmin=79 Zmax=109

Ufloor = (Q/(ti-te) - U2*A2 - U3*A3)/A1 = 0.318 W/(m².K)
  Q = 258.903 W
  ti = 20.00°C
  te = 0.00°C
  A1 = 27 m²
       Xmin=33 Xmax=78 Ymin=33 Ymax=78 Zmin=79 Zmax=79
  U2 = 0.323 W/(m².K)
       Xmin=0 Xmax=78 Ymin=78 Ymax=78 Zmin=109 Zmax=109
  A2 = 7.74001 m²
       Xmin=33 Xmax=33 Ymin=33 Ymax=78 Zmin=79 Zmax=109
  U3 = 0.323 W/(m².K)
       Xmin=78 Xmax=78 Ymin=0 Ymax=78 Zmin=109 Zmax=109
  A3 = 5.80501 m²
       Xmin=33 Xmax=78 Ymin=33 Ymax=33 Zmin=79 Zmax=109
```

Table 3. Derivation of ψ_g and U'_g in TRISCO (text output foundation_psi_3D_TR1.trc)

4. 2D numerical method

TRISCO data foundation_psi_2D_TR0.trc ; foundation_psi_2D_TR1.trc
BISCO data foundation_psi_BI0.bsc ; foundation_psi_BI1.bsc
Trisco2D data foundation_psi_no_wall.tr2 ; foundation_psi_wall.tr2

The 2D numerical method uses a floor that is infinitely long and has a width equal to the characteristic dimension of the floor B', calculated as follows:

$$B' = \frac{S_g}{0.5P} = \frac{l\,b}{\mathrm{l + b}} = 5.143\ \mathrm{m}B' = \frac{S_g}{0.5P} = \frac{l\,b}{\mathrm{l + b}} = 5.143\ \mathrm{m}$$

Figure 6 shows the 2D geometrical modelling rules according to EN ISO 10211 (b in drawing is B' in formula above).

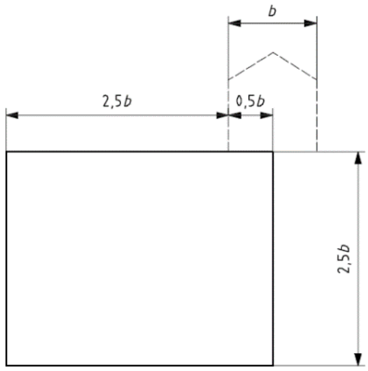


Figure 6: 2D geometrical modelling rules according to EN ISO 10211

Thermal transmittance of the floor U_g.

To derive the thermal transmittance of the floor U_g, the wall is replaced by an adiabatic condition and the foundation is replaced by ground and simulated in 2D (equivalent TRISCO or BISCO data mentioned above). The U_g-value is derived directly from the TRISCO (Table 5) or BISCO results and also in the spreadsheet shown in Table 4 (floor_U_psi_values.xlsx) using the formulas listed in that table. The value U_g = 0.307 W/m²K is close (slightly higher) than the method found using the 3D method, showing that the 2D method is a reliable.

Linear thermal transmittance of the wall/floor junction ψ_g.

To derive the linear thermal transmittance of a wall/floor junction ψ_g, a second simulation that considers the complete model is required (equivalent TRISCO or BISCO data mentioned above). The linear thermal transmittance ψ_g is derived in TRISCO (Table 6) or BISCO and in the spreadsheet shown in Table 4 (spreadsheet floor_U_psi_values.xlsx). The thermal transmittance U_g obtained above is defined in TRISCO or BISCO as an enforced U-value. The ψ-value obtained is slightly higher than the one obtained by the 3D method. Figure 7 and Figure 8 show the graphic results (isotherms) of both simulations.

Complete thermal transmittance of the floor U'_g.

It is possible to derive the complete thermal transmittance of the floor U'_g that includes the thermal bridge effects, using one single simulation (Table 4 and Table 6).

2D method	Q_{2D} [W/m]	$\Delta\theta_{ie}$ [K]	L_{2D} [W/mK]	l [m]	b [m]	B' (=2b_g) [m]	b_g [m]		U_g [W/m²K]
foundation_psi_2D_TR0.trc foundation_psi_BI0.bsc	15,787	20,0	0,7894	12,000	9,000	5,143	2,57		**0,307**

	Q_{2D} [W/m]	$\Delta\theta_{ie}$ [K]	L_{2D} [W/mK]		h [m]	b_g [m]	U_w [W/m²K]	h_w [m]	U'_g [W/m²K]	ψ_g [W/mK]
foundation_psi_2D_TR1.trc foundation_psi_BI1.bsc	25,555	20,0	1,2778		1,000	2,57	0,323	1,290	**0,335**	**0,072**

$$B' = \frac{S_g}{0.5P} = \frac{l\,b}{l+b} \qquad L_{2D} = \frac{Q_{2D}}{\Delta\theta_{ie}} \qquad U_g = \frac{L_{2D}}{b_g} \qquad U'_g = \frac{L_{2D} - U_w h_w}{b_g} \qquad \Psi_g = L_{2D} - U_w h_w - U_g b_g$$

Table 4. Derivation of U_g, U'_g and ψ_g.

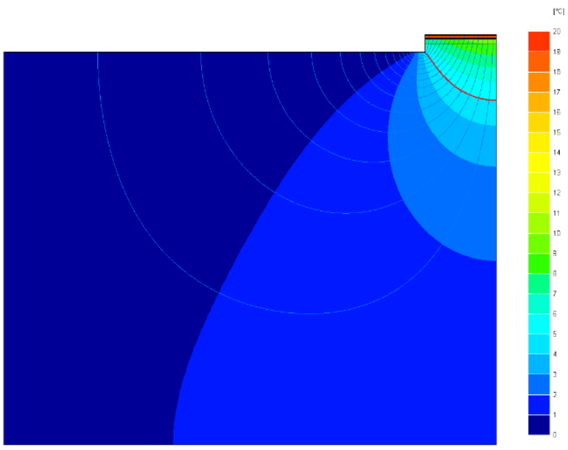


Figure 7
2D simulation without considering the junction: isotherms and heat flow lines

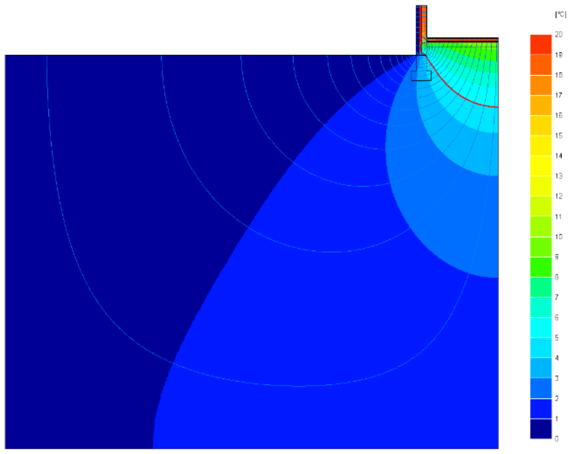


Figure 8
2D simulation for the complete 2D model: isotherms and heat flow lines

```
Ufloor = (Q/(ti-te))/A1 = 0.307 W/(m².K)
  Q = 15.787 W
  ti = 20.00°C
  te = 0.00°C
  A1 = 2.57 m²
       Xmin=66 Xmax=146 Ymin=0 Ymax=1 Zmin=114 Zmax=114
```

Table 5. Derivation U_g in TRISCO (text output foundation_psi_2D_TR0.trc)

```
Linear thermal transmittance (EN ISO 10211)
psi = (Q/(ti-te) - U1*A1 - U2*A2)/l = 0.072 W/(m.K)
  Q = 25.555 W
  ti = 20.00°C
  te = 0.00°C
  U1 = 0.307 W/(m².K)
       Xmin=0 Xmax=0 Ymin=0 Ymax=0 Zmin=0 Zmax=0
  A1 = 2.57 m²
       Xmin=66 Xmax=146 Ymin=0 Ymax=1 Zmin=132 Zmax=132
  U2 = 0.323 W/(m².K)
       Xmin=0 Xmax=146 Ymin=1 Ymax=1 Zmin=188 Zmax=188
  A2 = 1.29 m²
       Xmin=66 Xmax=66 Ymin=0 Ymax=1 Zmin=132 Zmax=188
  l = 1 m

Ufloor = (Q/(ti-te) - U2*A2)/A1 = 0.335 W/(m².K)
  Q = 25.555 W
  ti = 20.00°C
  te = 0.00°C
  A1 = 2.57 m²
       Xmin=66 Xmax=146 Ymin=0 Ymax=1 Zmin=132 Zmax=132
  U2 = 0.323 W/(m².K)
       Xmin=0 Xmax=146 Ymin=1 Ymax=1 Zmin=188 Zmax=188
  A2 = 1.29 m²
       Xmin=66 Xmax=66 Ymin=0 Ymax=1 Zmin=132 Zmax=188
```

Table 6. Derivation of ψ_g and U'_g in TRISCO (text output foundation_psi_2D_TR1.trc)

5. Simplified method

spreadsheet floor_U_psi_values.xlsx

The simplified method calculates U_g as follows:

1) Calculation of the characteristic dimension of the floor B',

$$B' = \frac{S_g}{0.5P} = \frac{l\,b}{l + b} = 5.143 \text{ m}$$

2) calculation of the total equivalent thickness

$d_t = w + \lambda(R_{si} + R_f + R_{se})$

w		[m]	total thickness of the wall
λ		[W/mK]	soil thermal conductivity
R_{si}		[m^2K/W]	internal surface resistance
R_f		[m^2K/W]	floor slab resistance
R_{se}		[m^2K/W]	external surface resistance

d_t = 3.736 m

3) calculation of the floor thermal transmittance U_g

if $d_t < B'$ $\quad U_g = \frac{2\lambda}{\pi B' + d_t} ln(\frac{\pi B'}{d_t} + 1)$

if $d_t \geq B'$ $\quad U_g = \frac{\lambda}{0.457B' + d_t}$

U_g = 0.34 W/m^2K.

No simplified method is available to calculate the linear thermal transmittance of the wall/floor junction.

6. Comparison of analytical, 2D and 3D method

The most detailed approach is the 3D numerical simulation.
The 2D numerical approach is a good estimation and results in a somewhat higher value of U_g and ψ_g.
The analytical approach allows only to calculate a conservative value of Ug.

	U_g [W/m^2K]	U'_g [W/m^2K]	ψ_g [W/mK]
3D method	**0.296**	**0.317**	**0.055**
2D method	**0.307**	**0.335**	**0.072**
analytical method	**0.336**	**/**	**/**

Table 7. Comparison of analytical method, 2D numerical method and 3D numerical method

7. References

EN ISO 13370:2017 *Thermal performance of buildings — Heat transfer via the ground — Calculation methods*

EN ISO 10211:2017 *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*