Università degli Studi di Padova
Dipartimento di Ingegneria Industriale

Energy and Buildings

Calculation of a thermal bridge using FEMM 4.2

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Objectives

Use a software for the calculation of thermal bridges in building constructions:

1. Calculate additional heat flow in thermal bridges (according to ISO 10211)
2. Assess the risk of surface condensation (according to ISO 13788)

FEMM 4.2 http://www.femm.info/wiki/Download

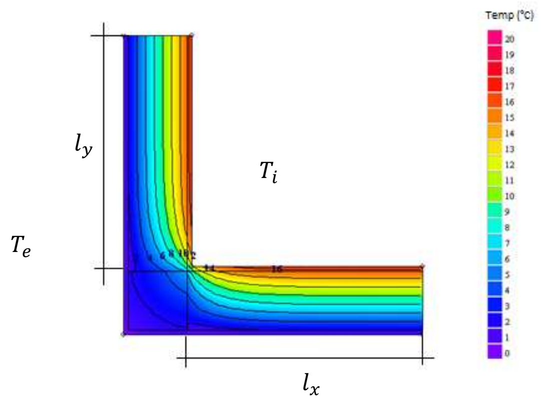
Calculation method of ISO 10211

Thermal coupling coefficient

The thermal coupling coefficient (**L_{2D} or L_{3D}**) is heat flow rate per temperature difference between two environments which are thermally connected by the construction under consideration.

$$L_{2D} = \frac{Q_{ie}}{l(T_i - T_e)} \left[\frac{W}{m\,K}\right]$$

Calculation of the linear thermal transmittance



1. Evaluate **temperature distribution** with 2D heat conduction calculation software
2. Integrate temperature difference over normal surface to get the heat flow rate q_{ie} and to calculate the thermal coupling coefficient L_{2D}
3. Calculate the linear thermal transmittance according to Standard

$$\Psi = L_{2D} - (U_x l_x + U_y l_y)$$

Calculation method of ISO 10211

Steps for the calculation of the thermal bridge with FEMM 4.2:

1. Import geometry from a .dxf file
2. Set material properties for each building component
3. Set boundary conditions
4. Create a mesh to discretize the domain
5. Run the FEM solver to calculate the temperature distribution
6. Integrate temperature difference over normal surface
7. Calculate L_{2D} , ψ and minimum surface temperature

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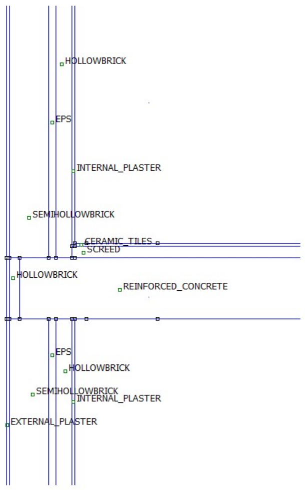
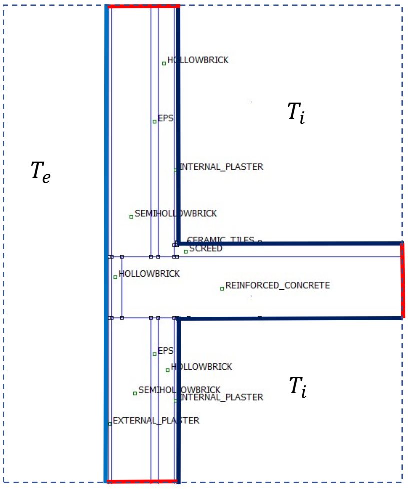


Intermediate floor junction

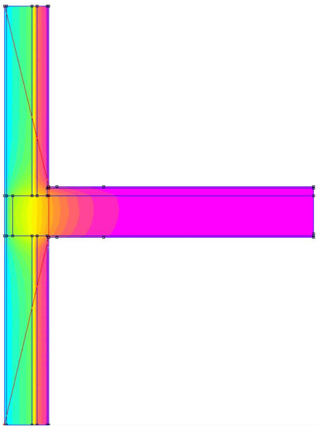
Material (eng)	Material (it)	Thermal conductivity k [W/(m K)]	Volumetric heat capacity c [MJ/(m3 K)]
Internal plaster	Intonaco interno (calce e gesso)	0.70	1.26
External plaster	Intonaco esterno (calce e cemento)	1.00	1.51
Reinforced concrete	Cemento armato	2.30	2.02
Screed	Massetto (calcestruzzo alleggerito con argilla espansa)	0.45	0.92
Semi-hollow bricks	Laterizio semipieno	0.70	1.01
Hollow bricks	Tramezza in laterizio	0.36	0.92
Ceramic tiles	Piastrelle di ceramica	1.20	1.68
Polistyrene (EPS)	Polistirene espanso (EPS)	0.04	0.05



Boundary condition of the II type
Adiabatic surface (q = 0)

Boundary conditions of the III type
h_{si} = 8 W/(m² K), T_i = 20°C
h_{se} = 25 W/(m² K), T_e = 0°C

Transmission heat transfer coefficient considering the thermal bridge



Calculated Heat Flux: q_{ie} [W/m]

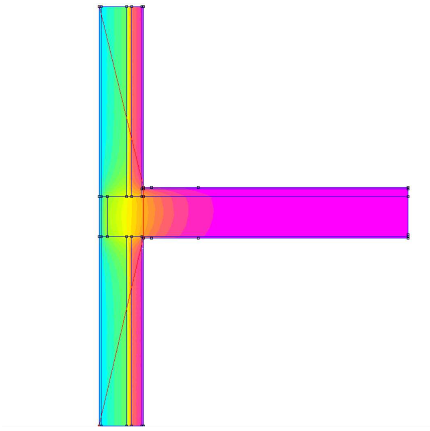
Thermal transmittance of the wall: U [W/(m² K)]

Thermal coupling coefficient 2D: $L_{2D} = \frac{q_{ie}}{l(T_i - T_e)}$ [W/(m K)]

Linear thermal transmittance: $\Psi = L_{2D} - \sum_{j=1}^{N_j} U_j\, l_j$

Transmission heat transfer coefficient: $H_T = \sum_k U_k A_k + \sum_j \Psi_j l_j$

Transmission heat transfer coefficient considering the thermal bridge



Calculated Heat Flux: q_{ie} = 53.23 W/m

Thermal transmittance of the wall: U = 0.585 W/(m^2 K)

Thermal coupling coefficient 2D: $L_{2D} = \frac{q_{ie}}{l(T_i - T_e)} = \frac{53.23}{1 \cdot (20-0)}$ = 2.66 W/(m K)

Linear thermal transmittance: $\Psi = L_{2D} - \sum_{j=1}^{N_j} U_j \, l_j$

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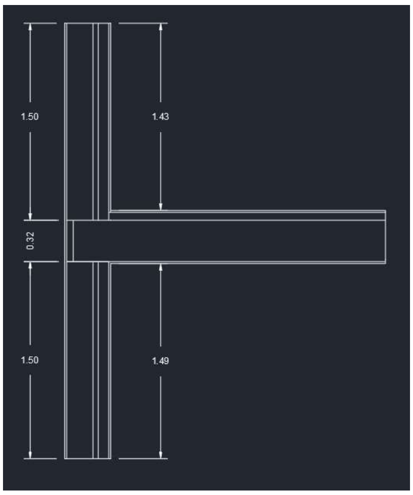


q_{ie} = 53.23 W/m U = 0.585 W/(m^2 K) L_{2D} = 2.66 W/(m K)

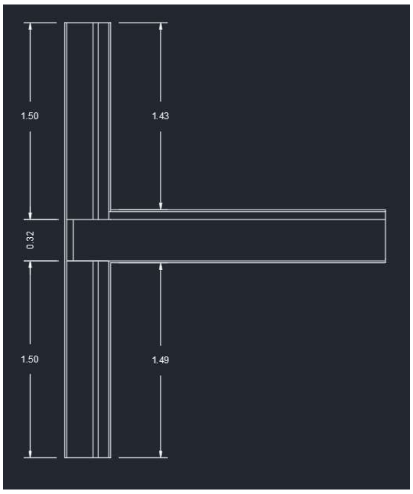
Linear thermal transmittance: $\Psi = L_{2D} - \sum_{j=1}^{N_j} U_j \, l_j$

$\Psi_i = 2.66 - 0.585 \cdot (1.43 + 1.49)$ = 0.95 W/(m K)

$\Psi_e = 2.66 - 0.585 \cdot (2 \cdot 1.5 + 0.32)$ = 0.72 W/(m K)

Transmission heat transfer coefficient

$$H_T = \sum_k U_k \, A_k + \sum_j \Psi_j \, l_j$$



q_{ie} = 53.23 W/m U = 0.585 W/(m² K) L_{2D} = 2.66 W/(m K)

Ψ_i = 0.95 W/(m K) Ψ_e = 0.72 W/(m K)

Transmission heat transfer coefficient

$$H_T = \sum_k U_k A_k + \sum_j \Psi_j l_j$$

$l_{tb} = 10\ m$ $h_{floor} = 3\ m$

$$H_{Ti} = 0.585 \cdot 10 \cdot 6 + 0.95 \cdot 10 = 44.63\ W/K$$

$$H_{Te} = 0.585 \cdot 10 \cdot 6.4 + 0.72 \cdot 10 = 44.63\ W/K$$

Temperature factor

Temperature factor at the internal surface

$$f_{R_{si}} = \frac{T_{si}(x,y) - T_e}{T_i - T_e}$$

Thermal insulation	LOW	HIGH
Surface temperature	$T_{si} \to T_e$	$T_{si} \to T_I$
Temperature factor	$f_{R_{si}} \to 0$	$f_{R_{si}} \to 1$