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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Thermal bridge

Definition (ISO 10211)

Part of the building envelope where the otherwise uniform thermal resistance is significantly changed

- by full or partial penetration of the building envelope by **materials** with a different **thermal conductivity**;
- by change in **thickness of the fabric** or difference between **internal and external areas** such as occur at wall/floor/ceiling junctions.

Thermal bridge

Change of thermal transmittance due to a discontinuity in the **materials** or **geometry** of the building envelope

- Additional heat flow has an impact on **energy needs**
- Local decrease of internal surface temperature may cause **condensation** problems in the heating season

Objectives

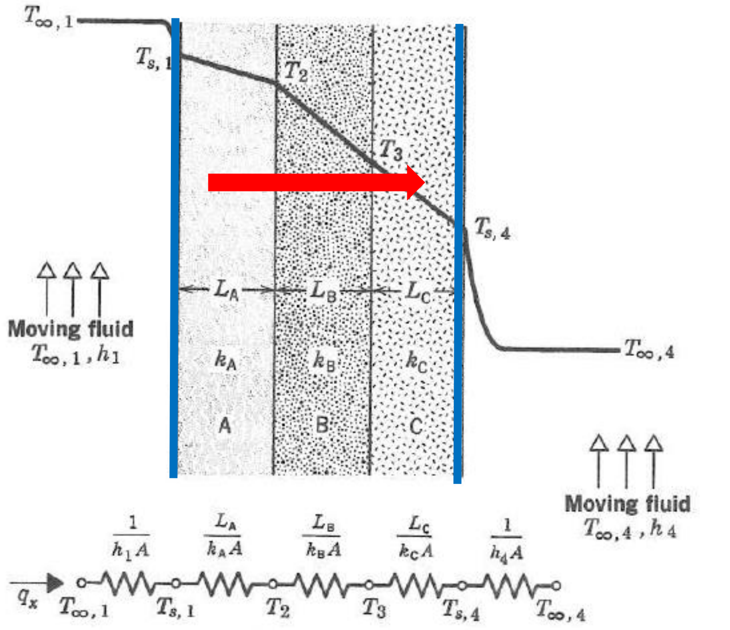
Use a software for the calculation of thermal bridges in building constructions:

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

Heat conduction in solids

Analytical solution for 1D steady-state problem on a composite wall



Equivalent thermal circuit for a composite wall
(Incropera & DeWitt, 1981)

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial T}{\partial x}\right) = 0$$

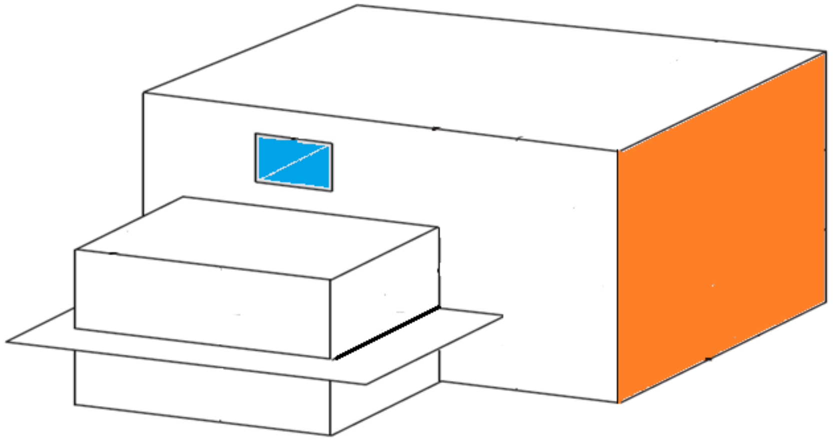
ELECTRICAL ANALOGY (1)

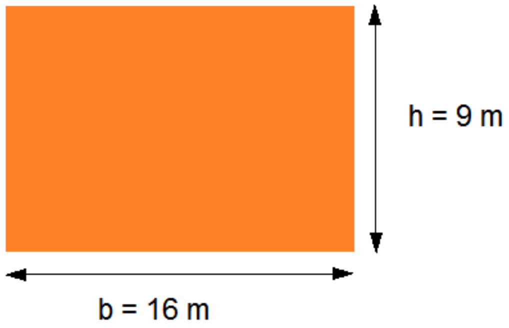
Fix temperature difference (T_1 - T_2) →

find heat flow q_x

$$q_x = \frac{(T_1 - T_2)}{\sum_i R_i}$$

Heat loss coefficient





A = b*h = 16*9 = 144 m2

U = 0.6 W/(m2 K)

$$q_T = H_T\,(\theta_i - \theta_e) \dashrightarrow H_T = \sum_i U_i\,A_i$$

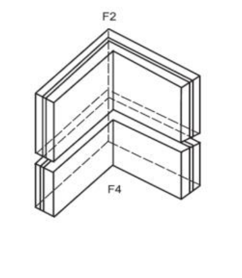
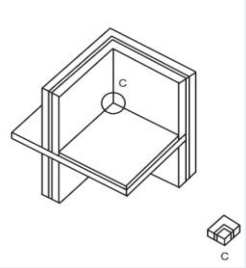
Transmission heat transfer coefficient

$$q_T = H_T\,(\theta_i - \theta_e)\quad \begin{cases} H_T = \sum_i U_i\,A_i \\ H_T = \sum_i U_i\,A_i + \sum_j \Psi_j\,l_j + \sum_k \chi_k \end{cases}$$

LINEAR THERMAL BRIDGES

POINT THERMAL BRIDGES

Calculation method of ISO 10211

Geometrical model	Example	Method
2D		Linear thermal transmittance, Ψ (W/(m K)) Thermal coupling coefficient from 2D calculation, L_{2D} (W/(m K)) $\Psi = L_{2D} - \sum_{j=1}^{N_j} U_j \, l_j$
3D		Point thermal transmittance, χ (W/K) Thermal coupling coefficient from 3D calculation, L_{3D} (W/K) $\chi = L_{3D} - \sum_{i=1}^{N_i} U_i \, A_i - \sum_{j=1}^{N_j} \Psi_j \, l_j$

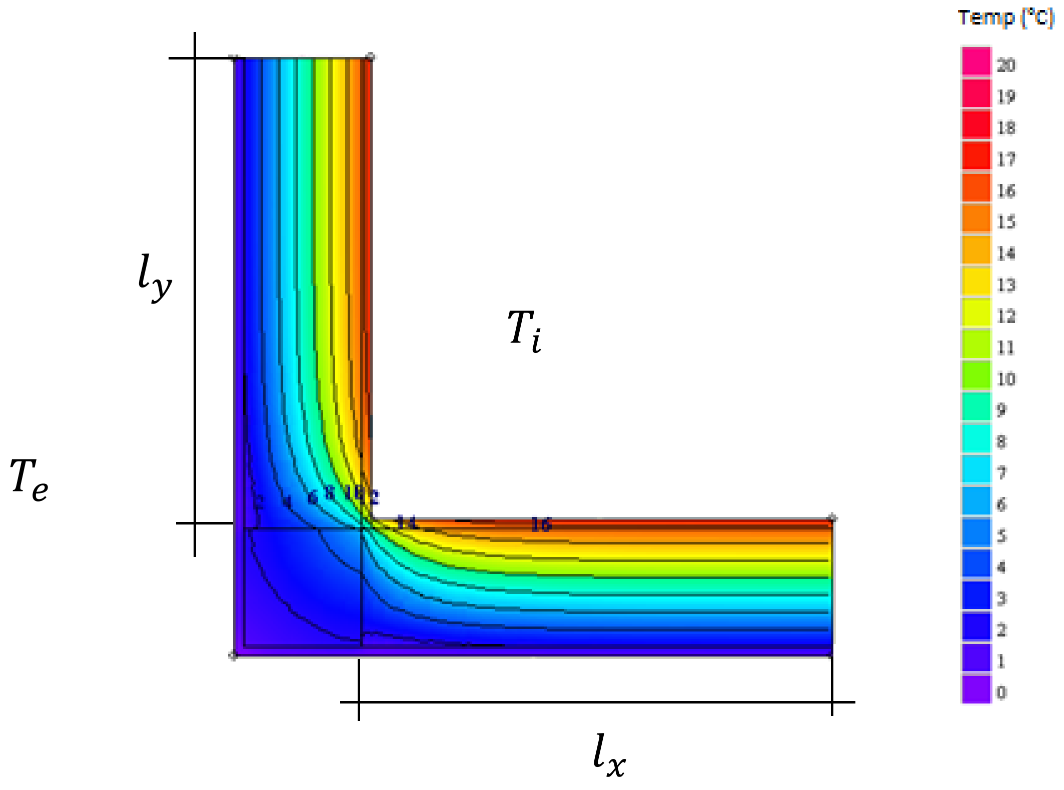
Calculation method of ISO 10211

Thermal coupling coefficient

The thermal coupling coefficient ($\boldsymbol{L_{2D}}$ **or** $\boldsymbol{L_{3D}}$) 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

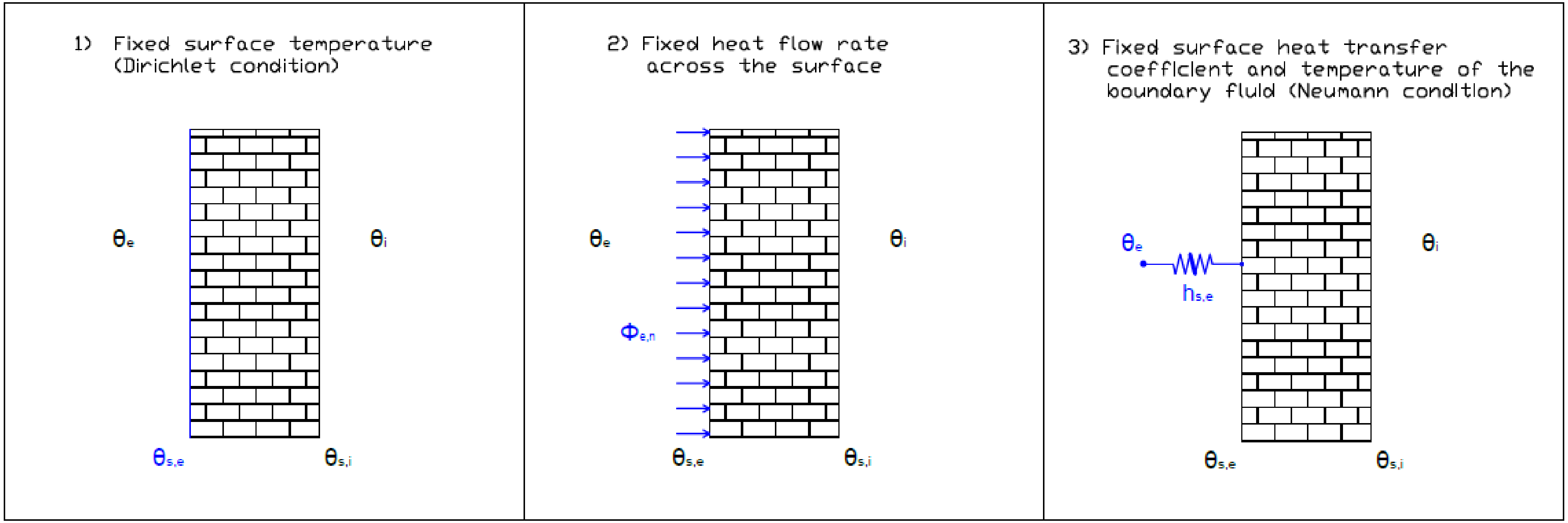


1. Evaluate **temperature distribution** with 2D heat conduction calculation software
2. Integrate temperature difference over normal surface to get the heat flow rate q_{ie} and to calculate the thermal coupling coefficient L_{2D}
3. Calculate the linear thermal transmittance according to Standard

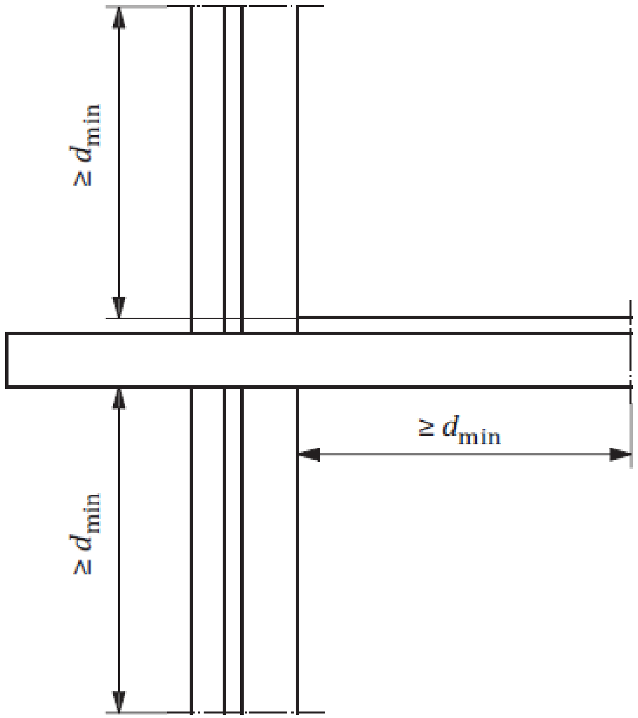
$$\Psi = L_{2D} - (U_x l_x + U_y l_y)$$

Calculation method of ISO 10211

Types of boundary conditions



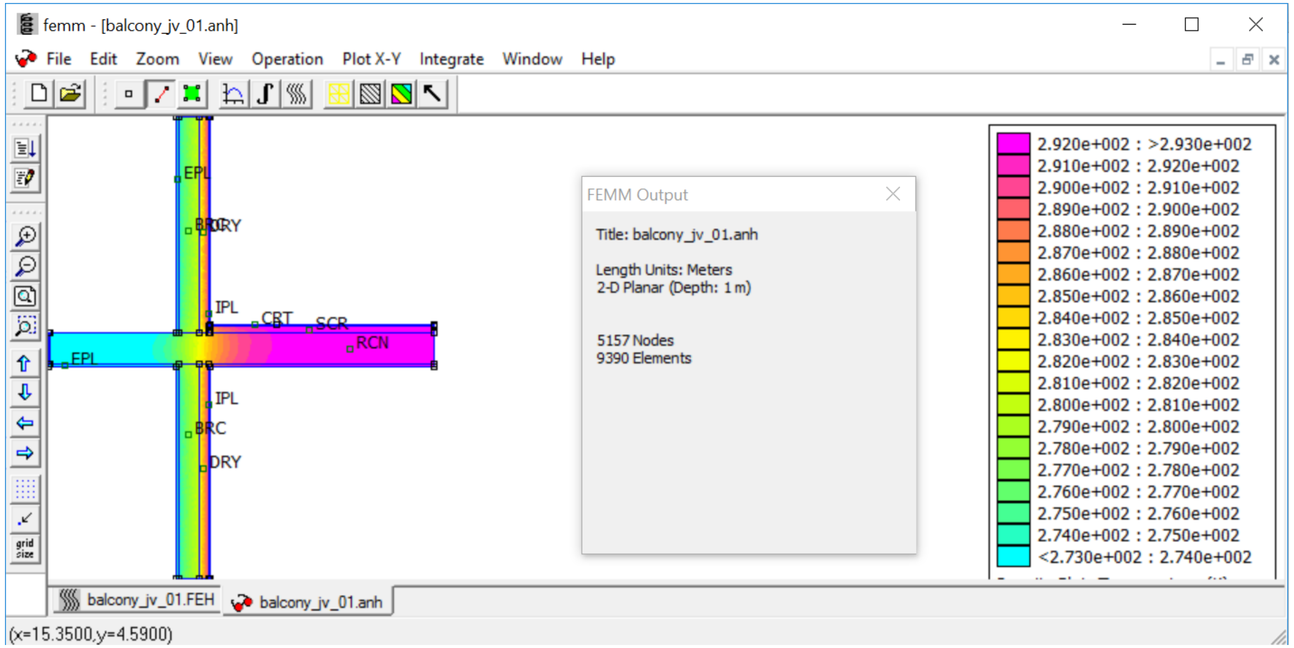
Calculation method of ISO 10211



Calculation of the linear thermal transmittance

Minimum distances of cut-off planes for 2D geometrical models is a function of envelope thickness according to the Standard

FEMM 4.2

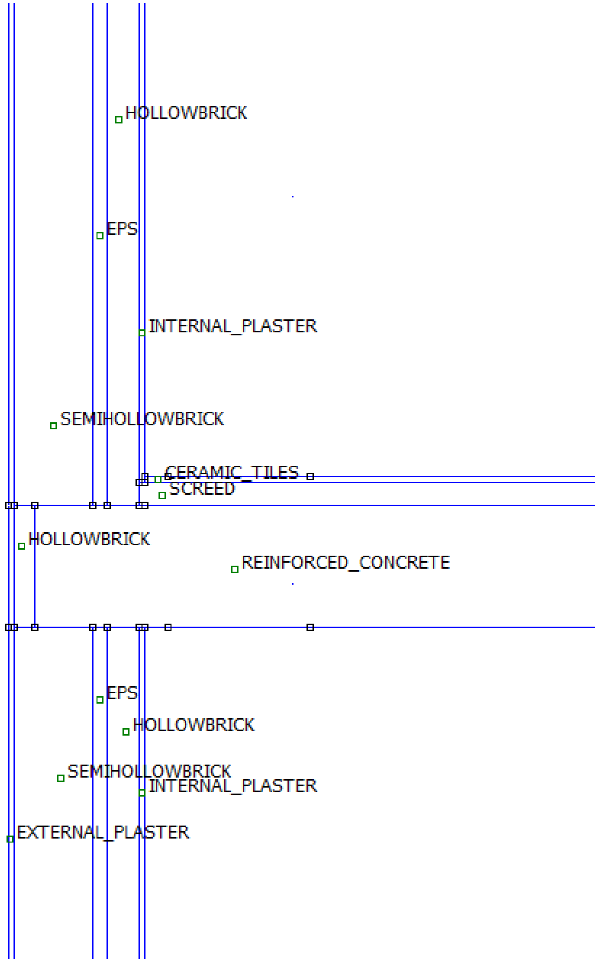


The FEMM software is a **finite element** package for solving **2D planar** and axisymmetric magnetic, electrostatic, **steady-state heat conduction**, and current flow **problems**.

Calculation method of ISO 10211

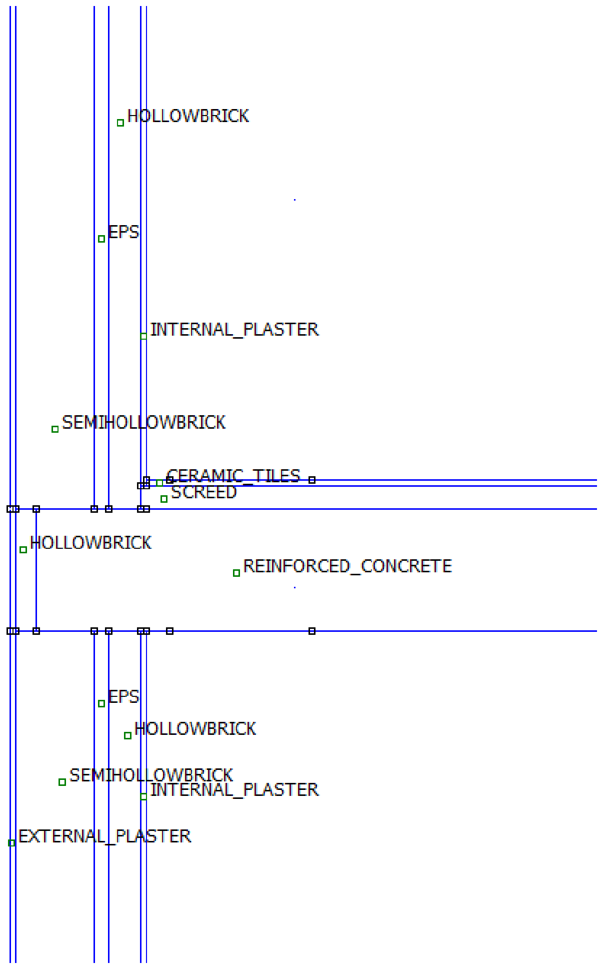
Steps for the calculation of the thermal bridge with FEMM 4.2:

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



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



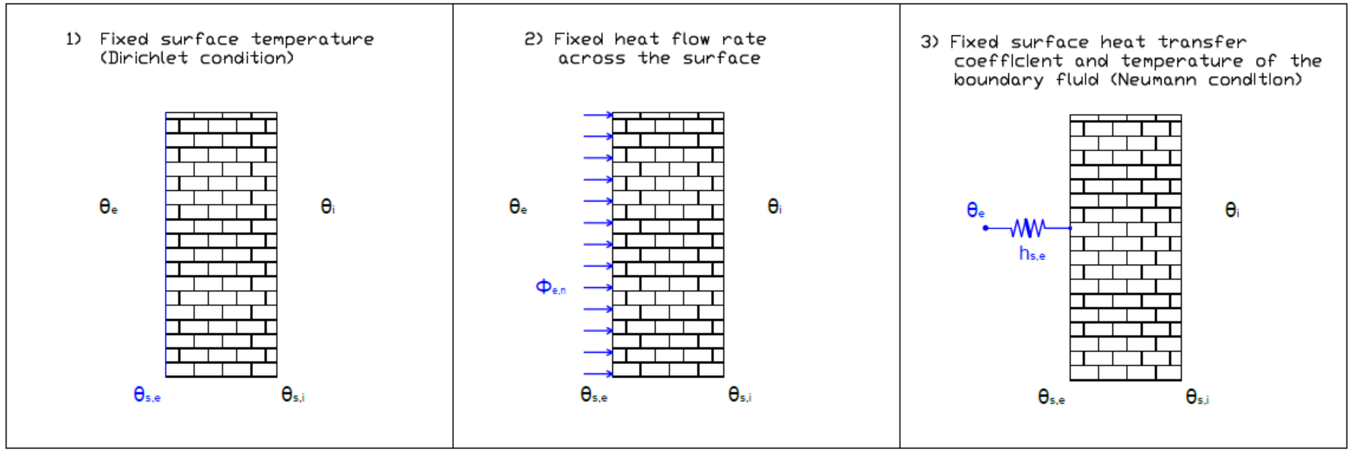
Boundary condition of the III type

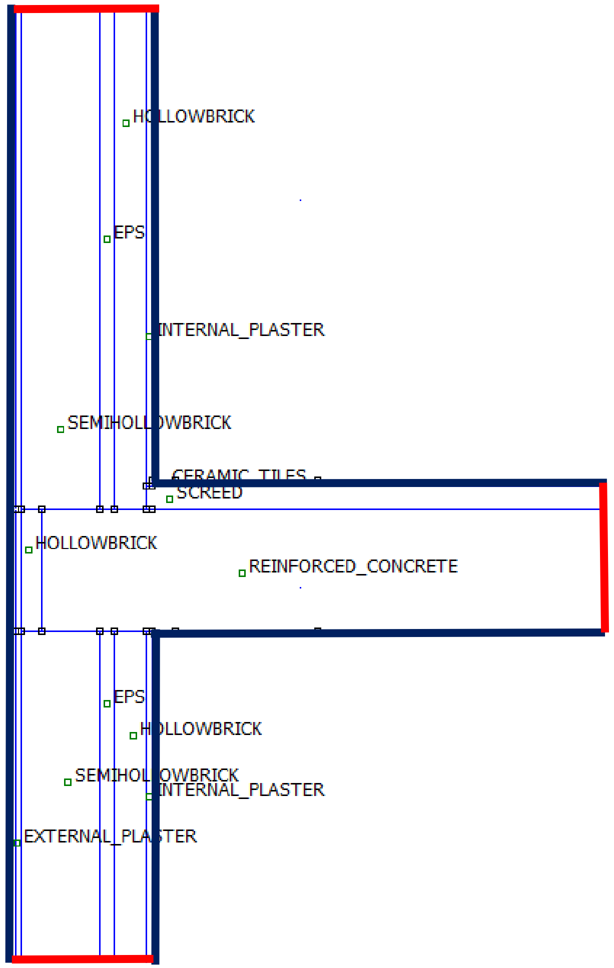
h_{si} = 8 W/(m2 K)

h_{se} = 25 W/(m2 K)

Adiabatic surface (q = 0)

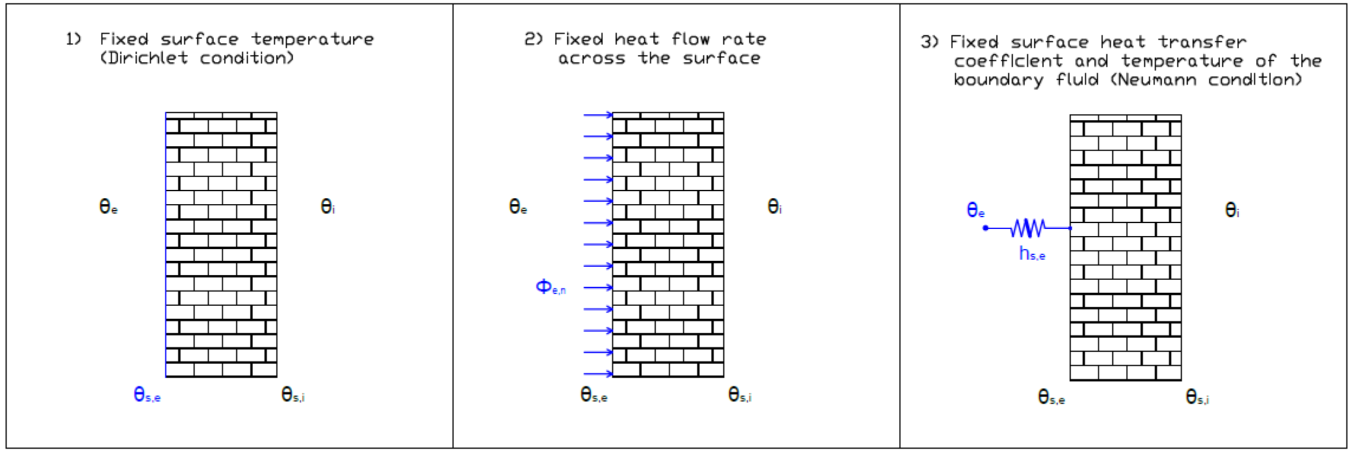
Boundary condition of the II type

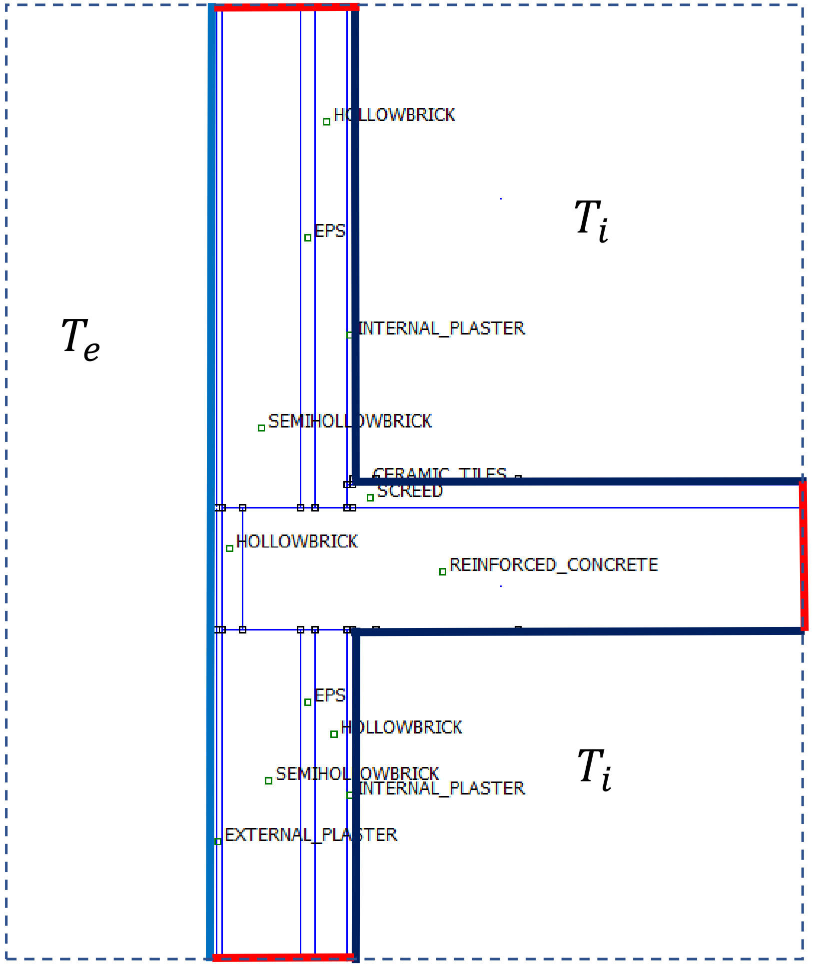




Boundary condition of the III type
h_{si} = 8 W/(m2 K)
h_{se} = 25 W/(m2 K)

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





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