UNIVERSITEIT GENT

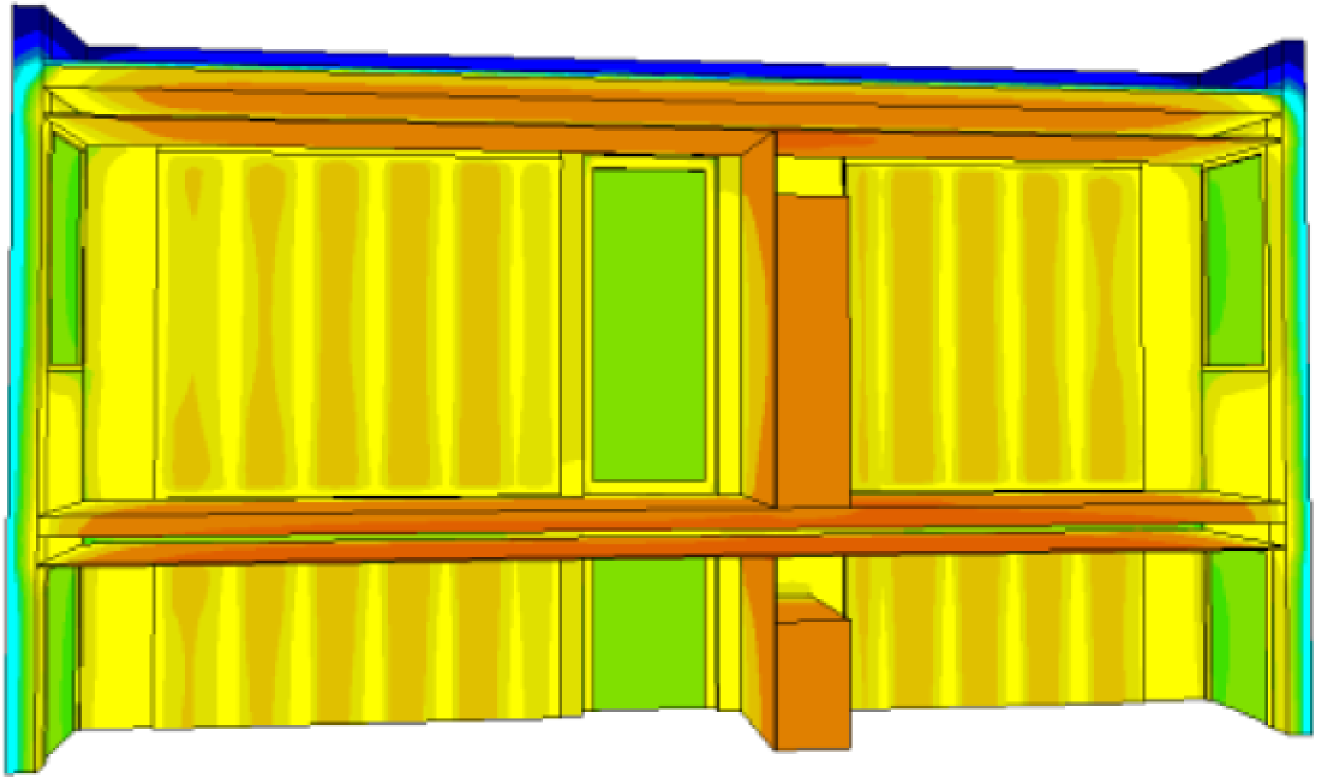
FACULTEIT INGENIEURSWETENSCHAPPEN

Thermal Bridges

Calculation, criteria, impact, and practical application

Prof. Nathan Van Den Bossche

Building Physics and Services, Ghent University, Belgium



$$\Phi = A \cdot U \cdot (T_i - T_e)$$

$$= A \cdot \frac{(T_i - T_e)}{R_{TOT}}$$

$$R_{TOT} = \frac{1}{h_e} + \sum R_i + \frac{1}{h_i}$$

Often calculated with U_{eq}, comprising impact of wall ties, studs

Overview

- **Introduction:**
  - Definition
  - Degradation
- Thermal performance criteria
- Thermal optimization
- Application in practice
- Steel construction

Thermal bridge – ISO 10211

thermal bridge
part of the building envelope where the otherwise uniform thermal resistance is significantly changed by:

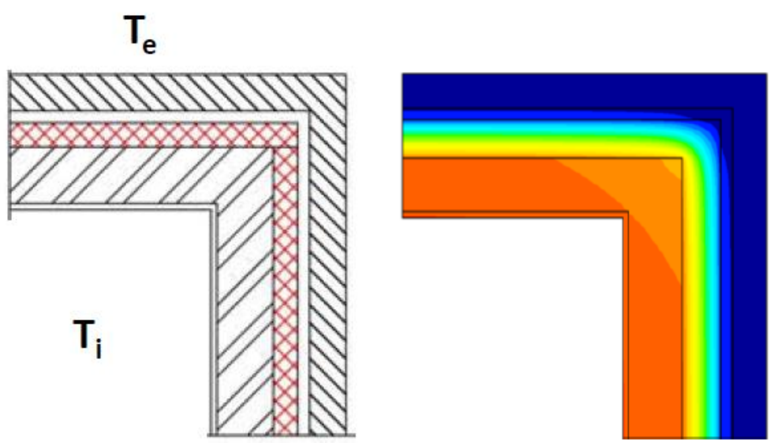
a) full or partial penetration of the building envelope by materials with a different thermal conductivity

and/or

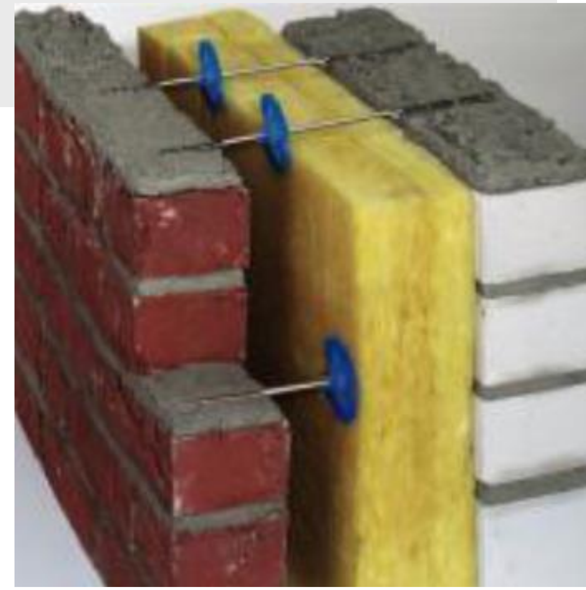
b) a change in thickness of the fabric

and/or

c) a difference between internal and external areas, such as occur at wall/floor/ceiling junctions

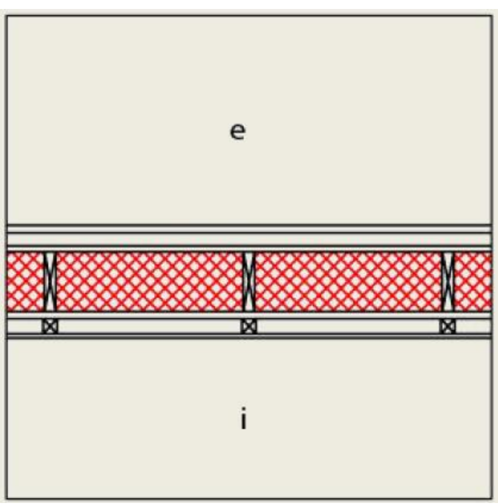


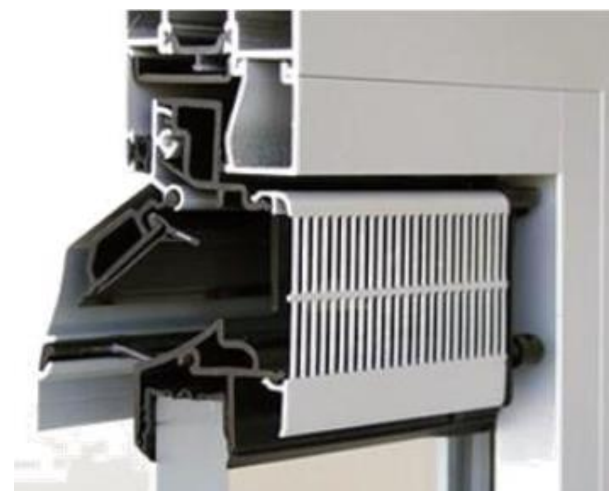
Thermal bridge – Belgium



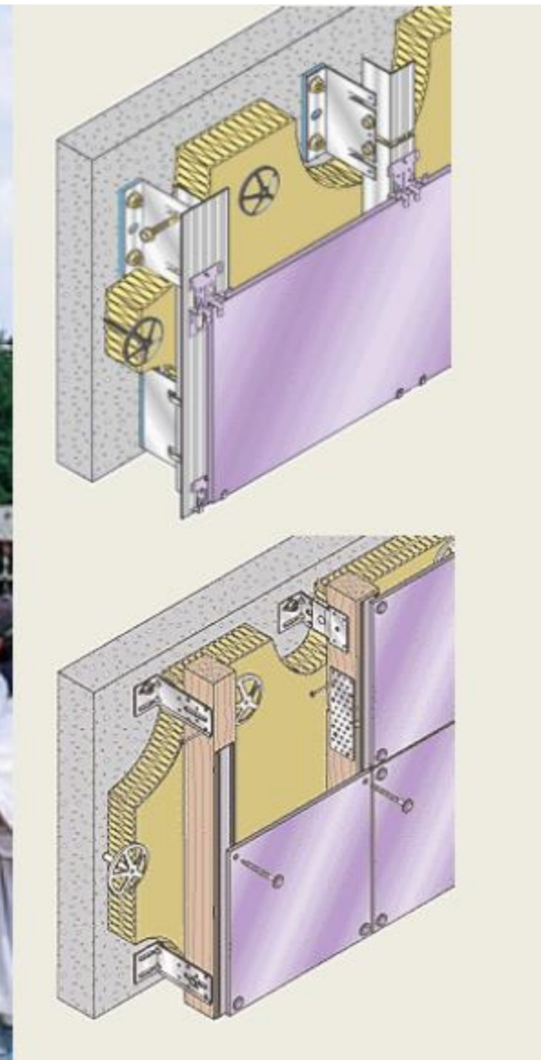
Exceptions

- Typical system components
  e.g. wood studs, wall ties





Thermal bridge – Belgium

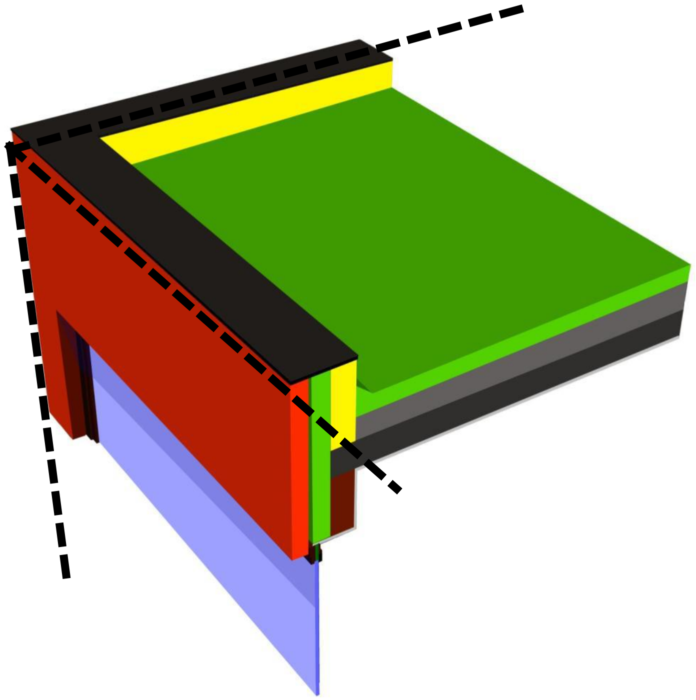


Thermal bridge – Belgium

Exceptions

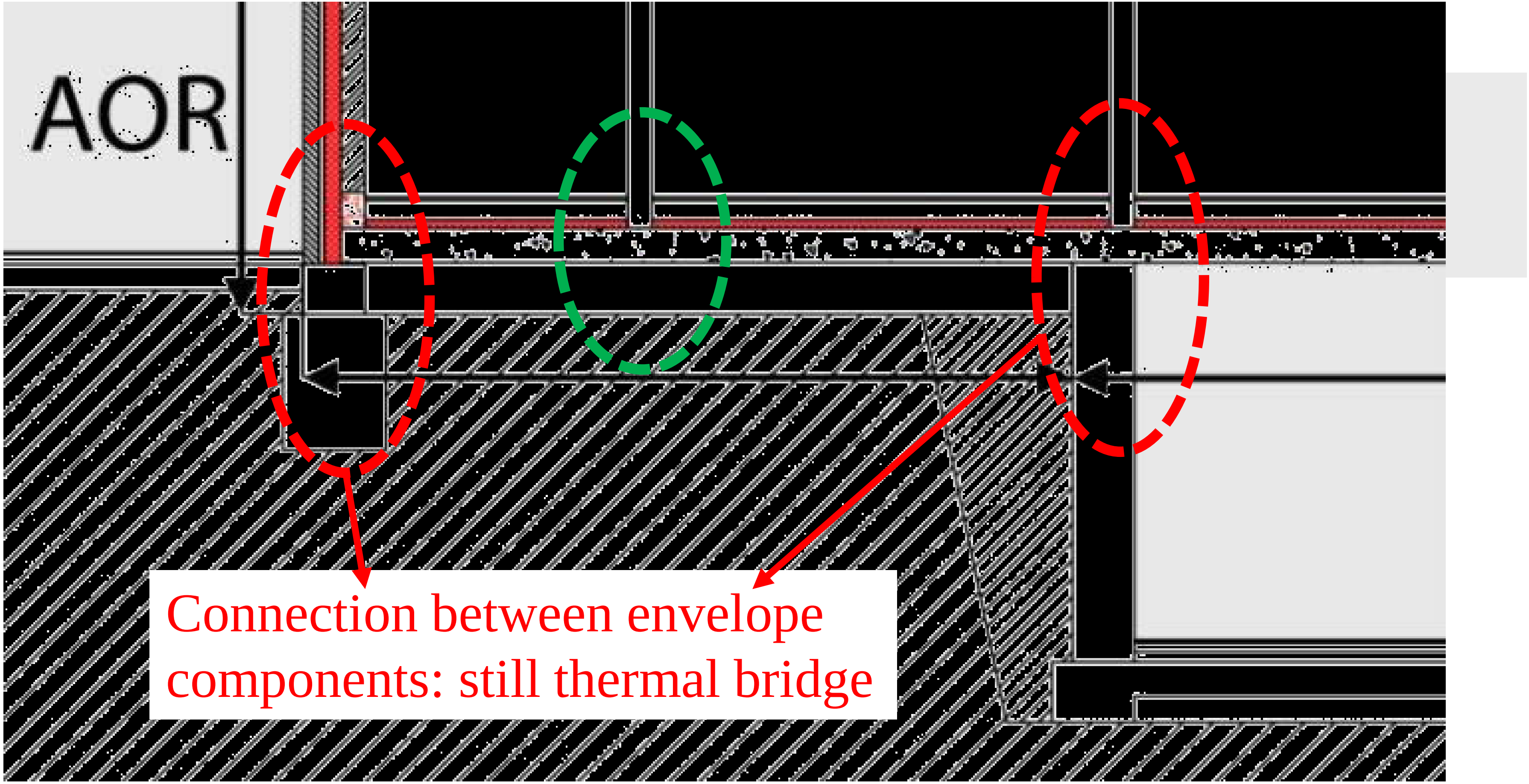
- Typical system components
  e.g. wood studs, wall ties
- Technical services transits
  e.g. gutter, chimney

Thermal bridge – Belgium



Exceptions

- Typical system components
  e.g. wood studs, wall ties
- Technical services transits
  e.g. gutter
- Intersection of 2 or more linear thermal bridges
  e.g. window detail sill-side

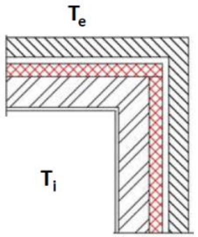


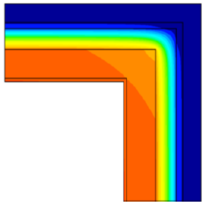
- Construction nodes in direct contact with the grond
e.g. interior walls on concrete floor

Thermal bridge – Belgium

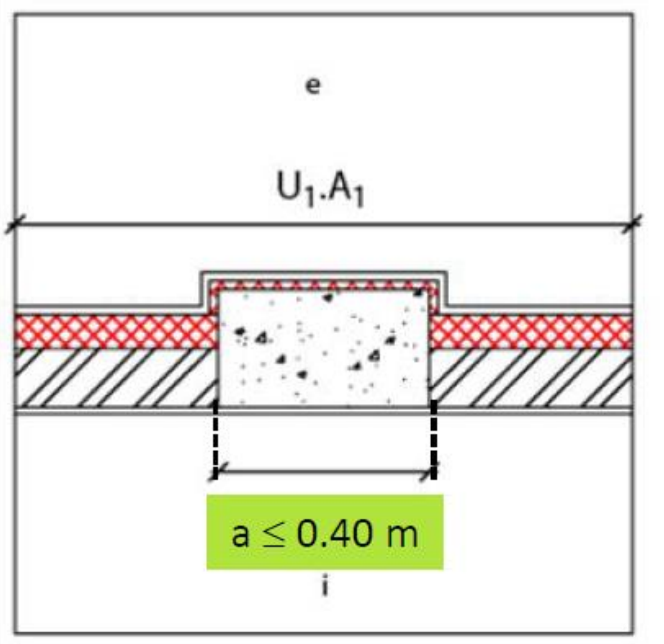
Exceptions

- Typical system components
  e.g. wood studs, wall ties
- Technical services transits
  e.g. gutter
- Intersection of 2 or more linear thermal bridges
  e.g. window detail sill-side
- Construction nodes in direct contact with the grond
  e.g. interior walls on concrete floor
- When the insulation layer is continuous
  e.g. exterior corner





Thermal bridge – Belgium



Exceptions

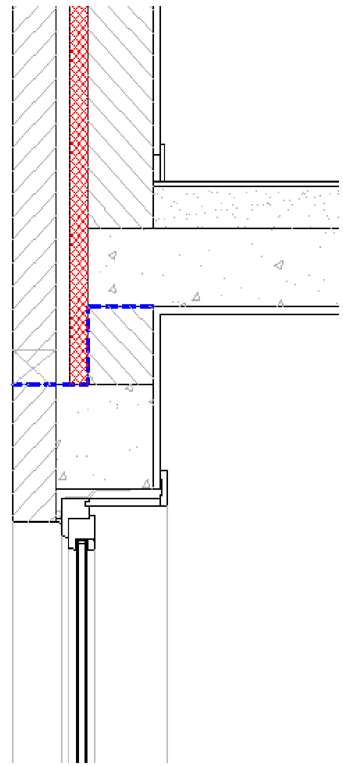
- Typical system components
  e.g. wood studs, wall ties
- Technical services transits
  e.g. gutter
- Intersection of 2 or more linear thermal bridges
  e.g. window detail sill-side
- Construction nodes in direct contact with the grond
  e.g. interior walls on concrete floor
- When the insulation layer is continuous
  e.g. exterior corner
- When it is a “surface”

Degradation

- Surface condensation
- Mould growth
- Interstitial condensation

Thermal bridges in masonry cavity wall construction

1970’s-1980’s: Problems of mould growth at structural connections between interior and exterior masonry leaf

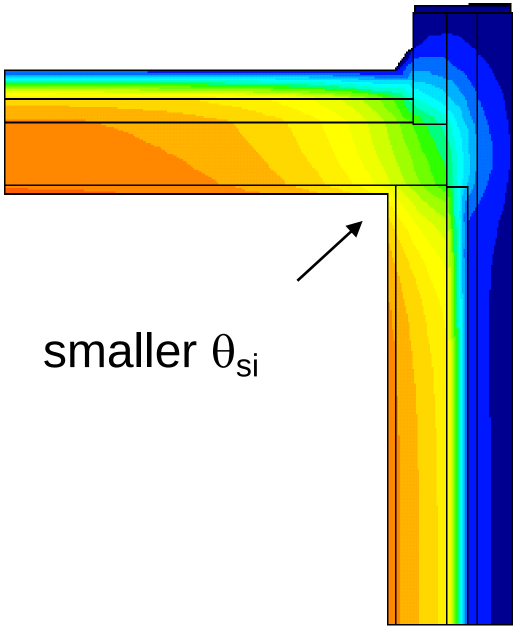


mould growth

Temperature factor/index

(dimensionless surface temperature)

$$f_{0.2} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$



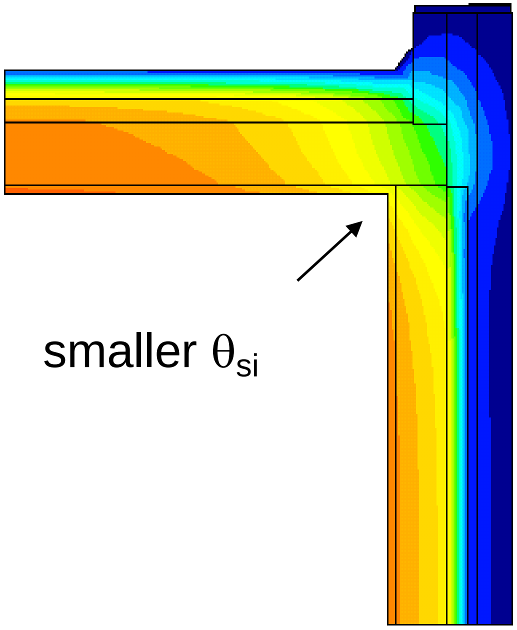
Suffix 0.2 relates to the reduced heat transfer coefficient (combined effect of convection and radiation – 5W/m²K)

mould growth

Temperature factor/index

(dimensionless surface temperature)

$$f_{0.2} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$



Suffix 0.2 relates to the reduced heat transfer coefficient (combined effect of convection and radiation – 5W/m²K)

To avoid mould growth: RH < 80%

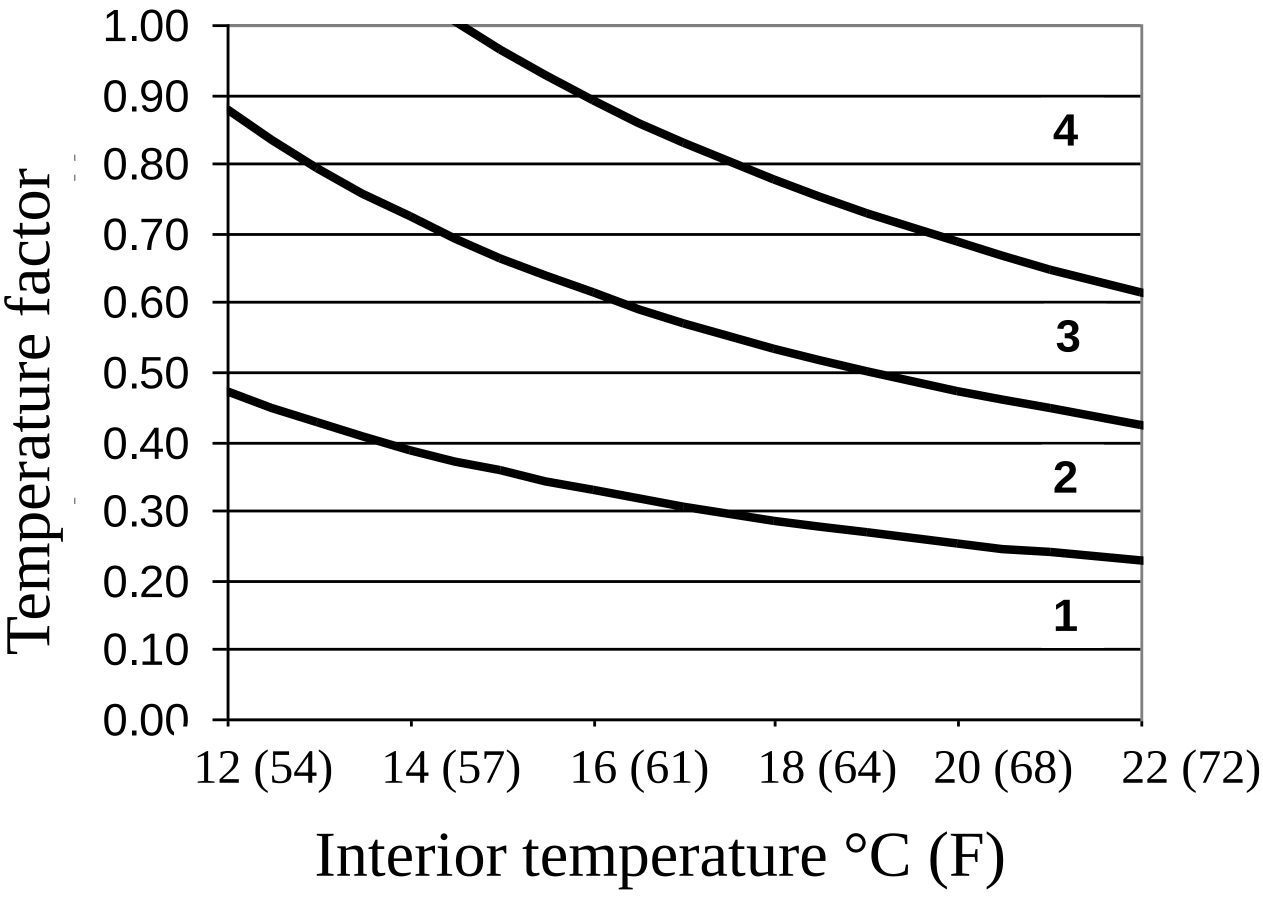
$$f \geq \frac{\theta_D(p_i / 0.8) - \theta_e}{\theta_i - \theta_e}$$

$$\theta_D(x) = \frac{\ln(p/611) \cdot b}{a - \ln(p/611)}$$

$$p \leq 611 : a = 22.44; b = 272.44$$

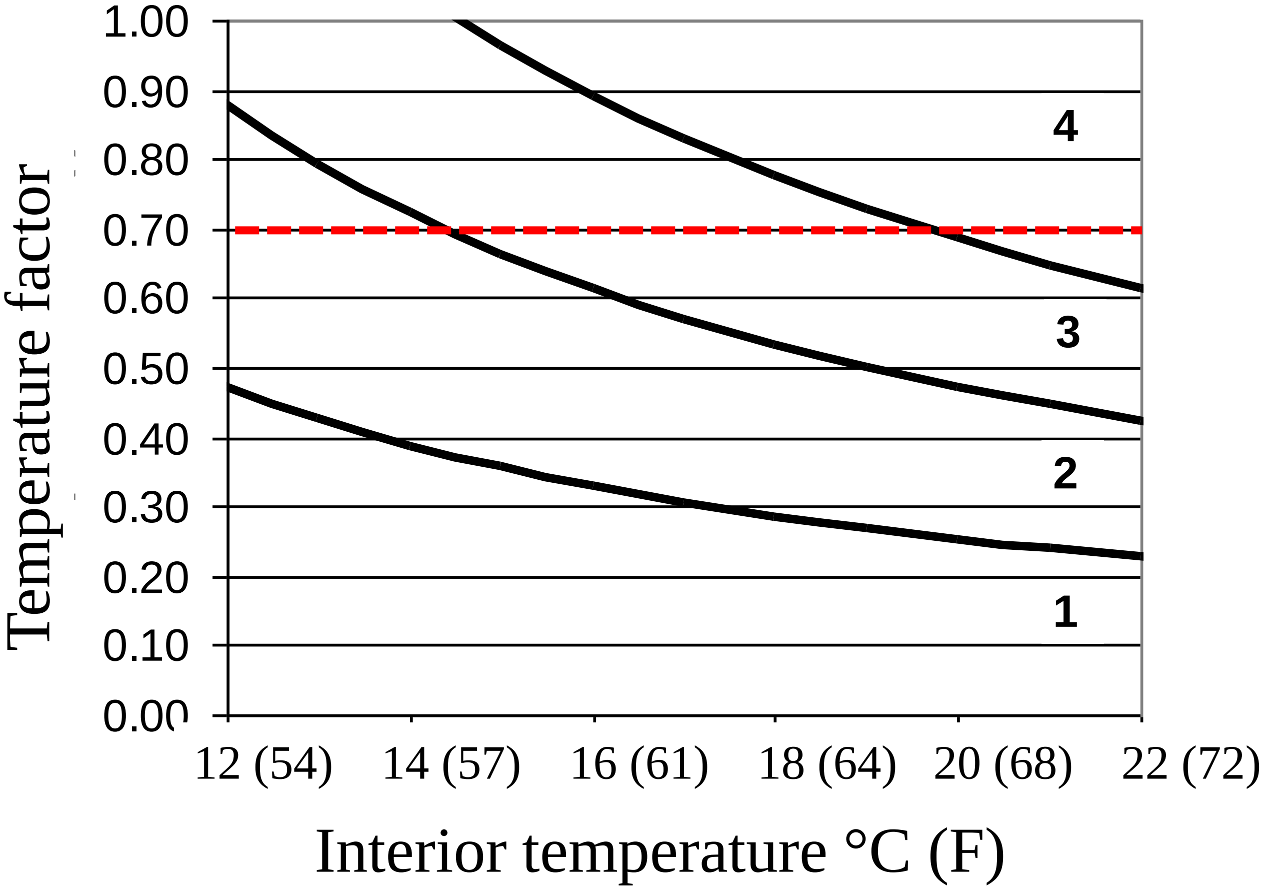
$$p > 611 : a = 17.08; b = 234.18$$

Criteria – mould growth



Criteria – mould growth

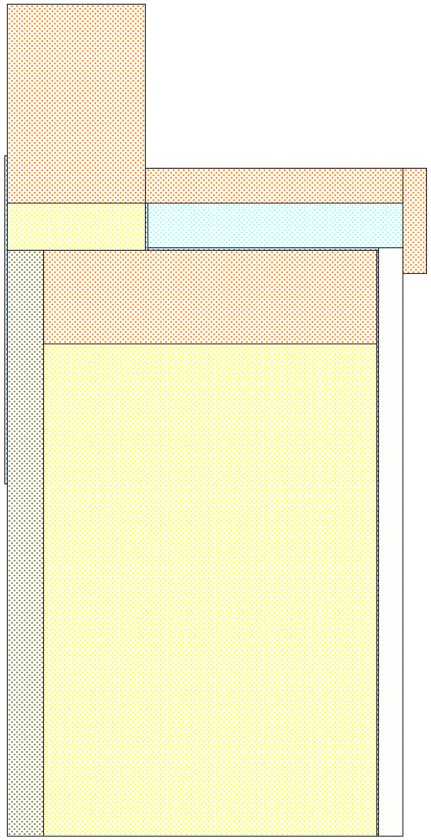
Design requirement mould control:
$f_{0.2} \geq 0.7$

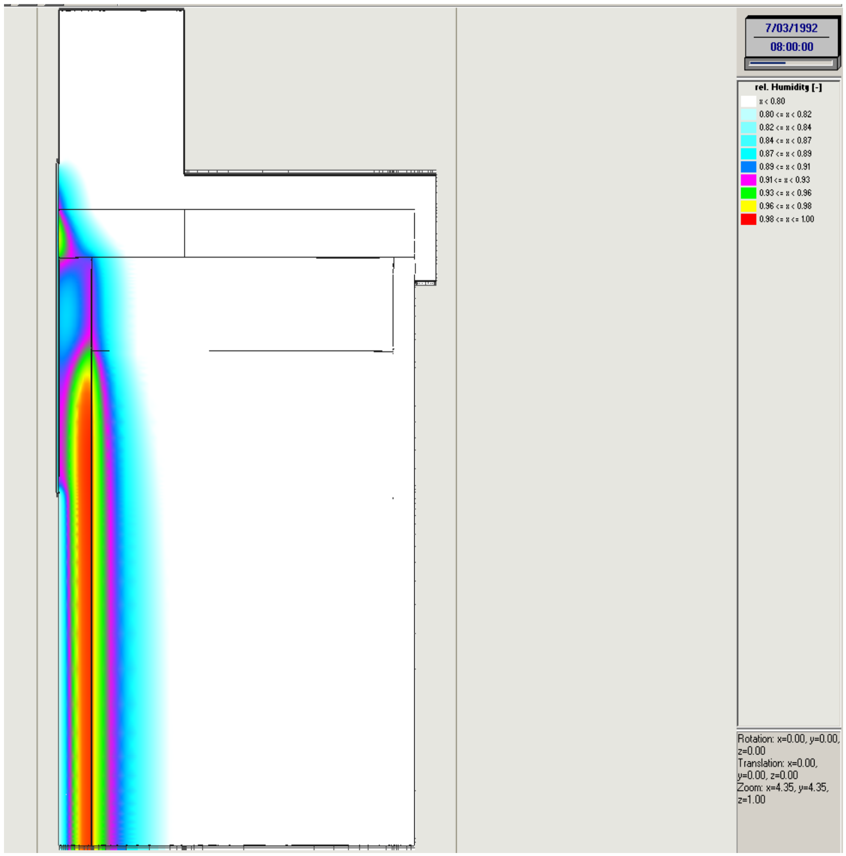


Criteria – interstitial condensation

Heat-Air-Moisture simulations

Outside the scope of this workshop

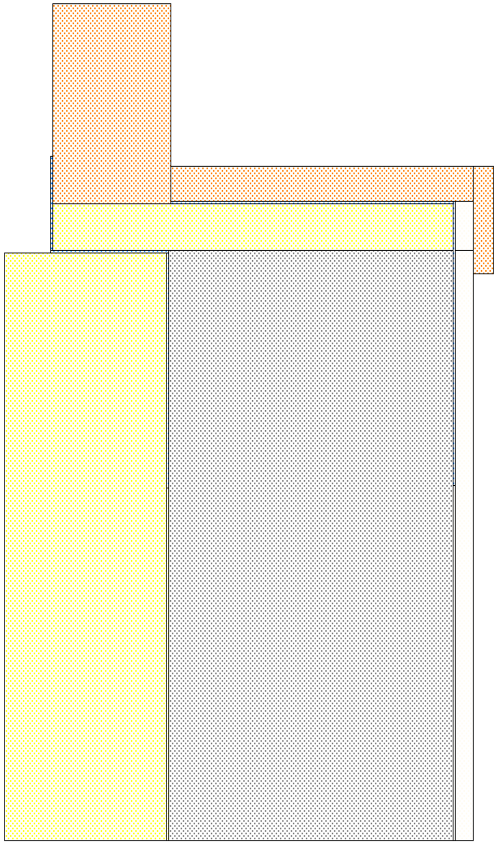


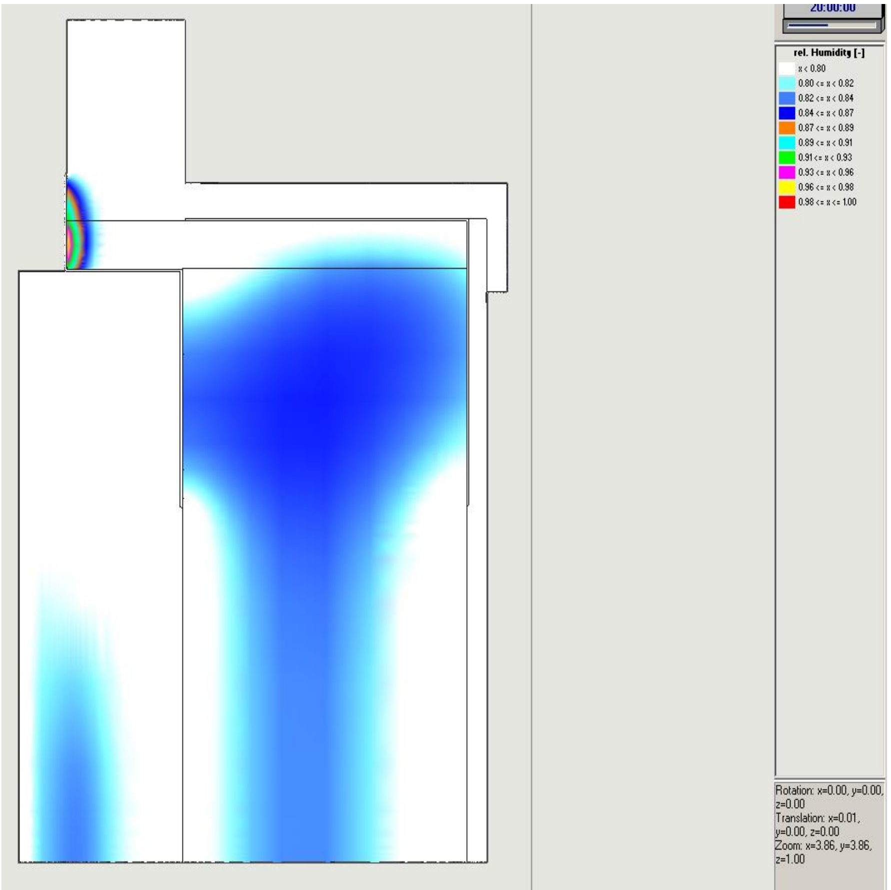


Criteria – interstitial condensation

Heat-Air-Moisture simulations

Outside the scope of this workshop





Overview

- Introduction:
  - Definition
  - Degradation
- **Thermal performance criteria**
- Thermal optimization
- Application in practice
- Steel construction

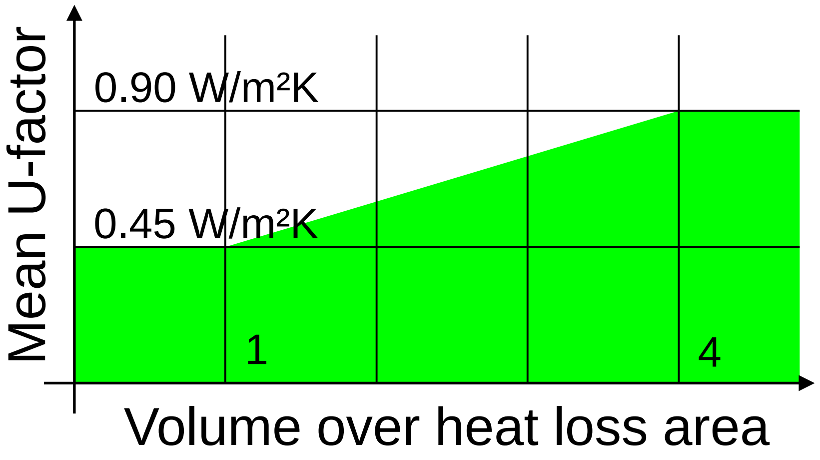
Thermal performance criteria

Energy performance regulation since 2006

- New Flemish legislation to limit transmission heat loss and primary energy use
- Larger relative contribution of thermal bridges
- Need for improved constructional details
- Guidelines on thermal bridges in new legislation
  - Not included yet

Research questions:

- Quantification of thermal bridge influence in residential construction?
- Limits for minimized heat loss at building component junctions?



Definition linear thermal transmittance (W/mK)

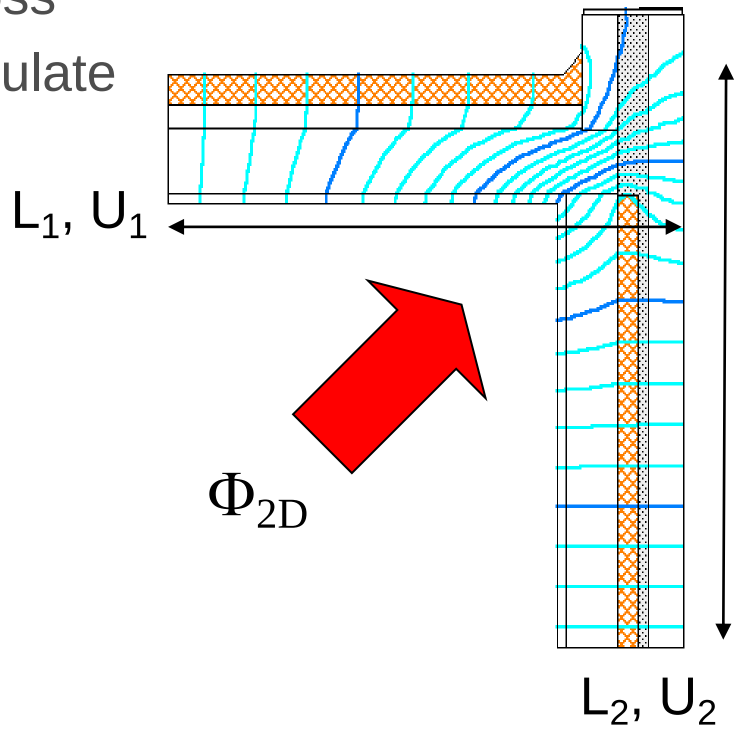
- Measure for additional heat loss compared to 1D-transmission heat loss
- Depends on dimensions used to calculate heat loss area
  - Differs from country to country
- By convention:

  Exterior dimensions (Belgium)

  Exterior insulation (Germany)

  Interior dimensions (France)

Numerical calculation (2D)



Indicator:

$$\Psi_e = \frac{\Phi_{2D}}{(\theta_i - \theta_e)} - \sum_n (L_i U_i)$$

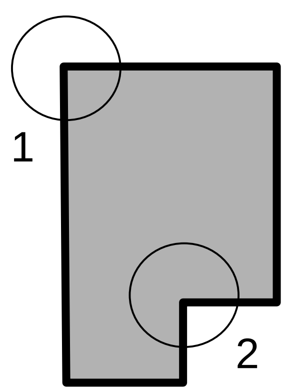
Linear thermal transmittance: influencing factors

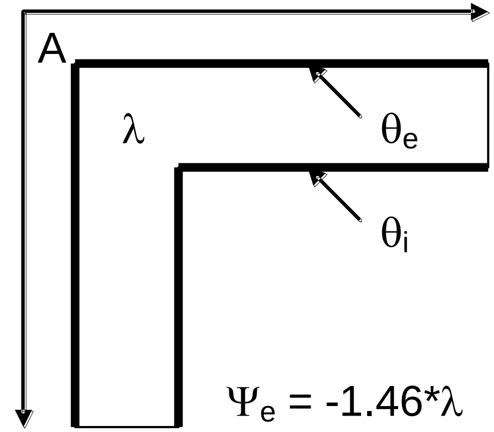
- Ψ-value not only depends on thermal quality of the detailing

Also:

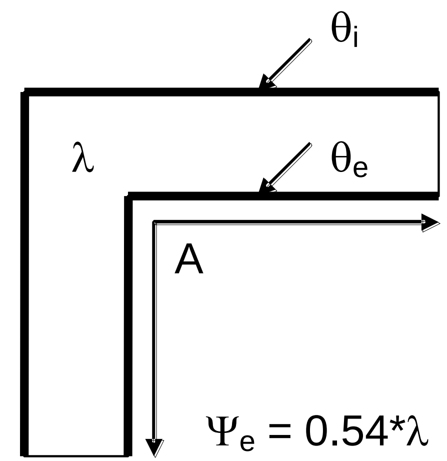
- Insulation thickness
- Position of thermal insulation
- Difference between interior and exterior area (corners)

- Important to consider when specifying limiting values



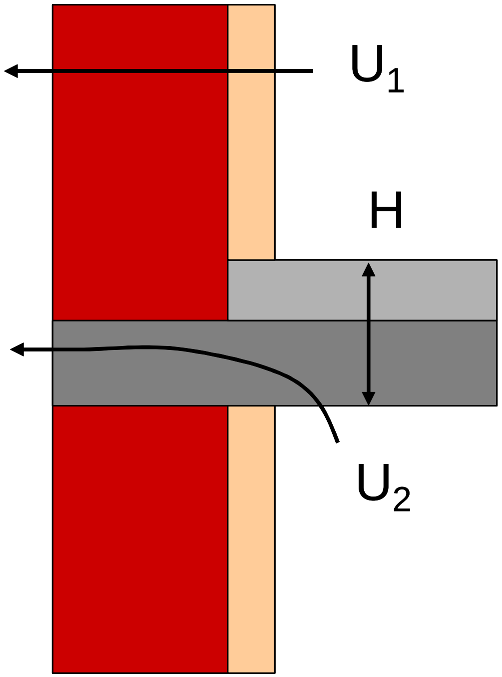


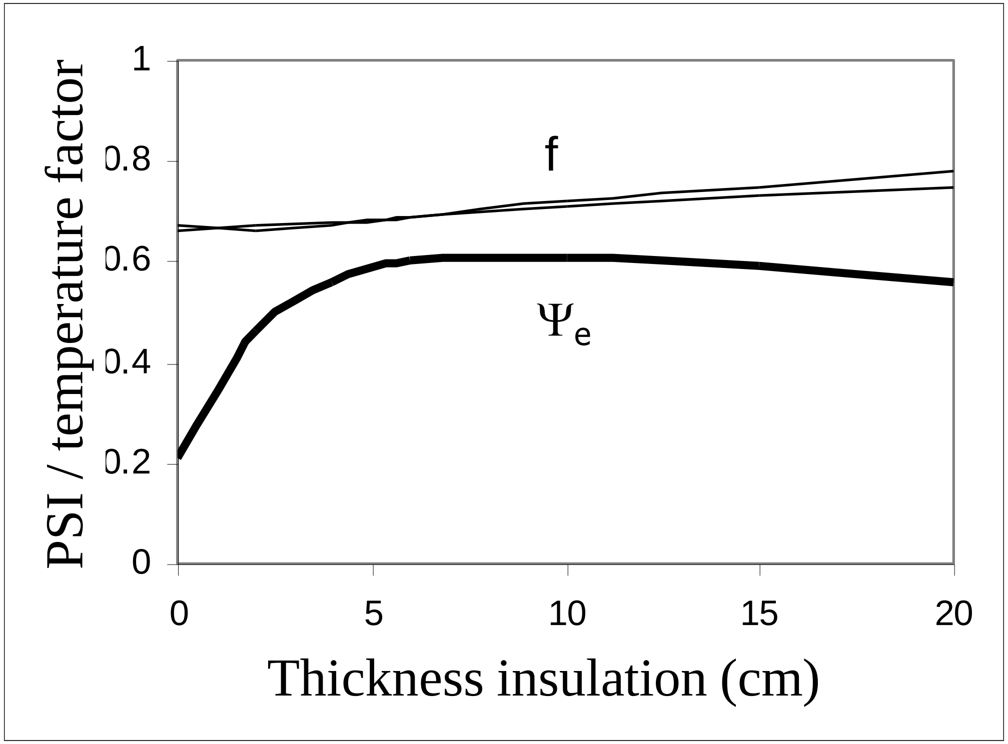
Exterior corner



Interior corner

Linear thermal transmittance: influencing factors





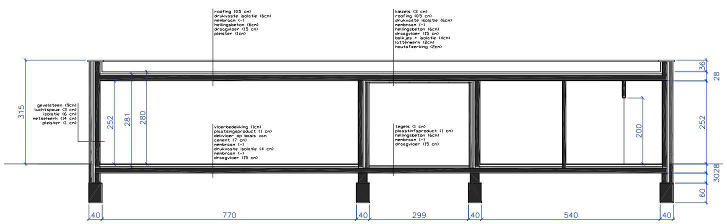
Influence of building details on transmission heat loss

Methodology

- 5 reference dwellings with same useful floor area
  - Different compactness
- Traditional construction: masonry cavity walls, concrete floors, wood frame roofs
- 3 levels of thermal quality in constructional detailing
  - ‘Business as usual’
  - ‘Standard’
  - ‘Thermal bridge avoidance’
- Calculate contribution of thermal bridges to overall transmittance:

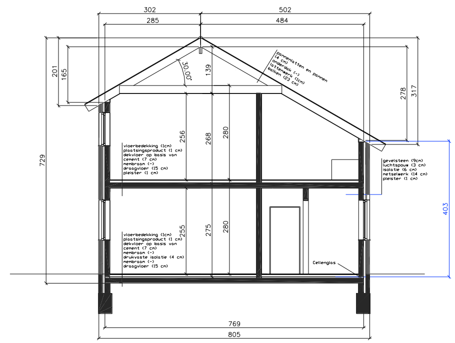
$$\Delta U_{TB} = \sum \Psi_j L_j / \sum A_i$$

Reference dwellings



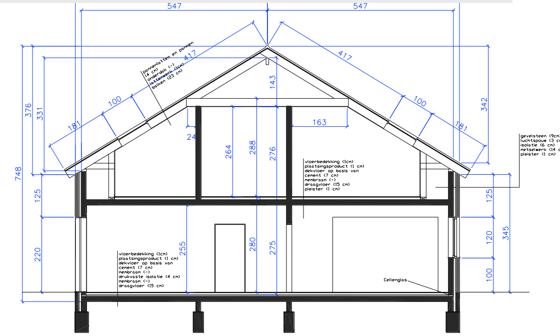
Snede AA'

Detached bungalow
L/A = 0.5 m/m², C = 0.9 m



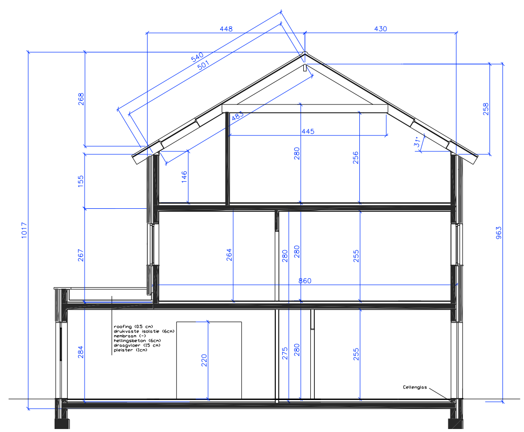
Doorsnede BB'

Detached house
L/A = 0.7 m/m², C = 1.3 m

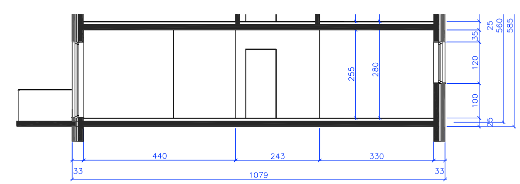


Snede AA'

Semi-detached
L/A = 0.7 m/m², C = 1.6 m



Terraced house
L/A = 0.9 m/m², C = 2.1 m



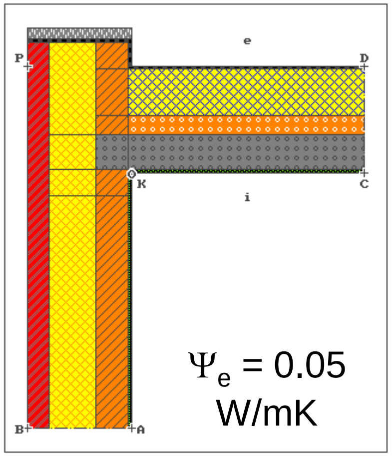
Snede AA'

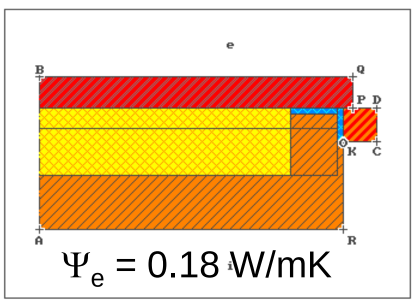
Appartment
L/A = 0.8 m/m², C = 3.8 m

Linear thermal transmittance for 23 junctions

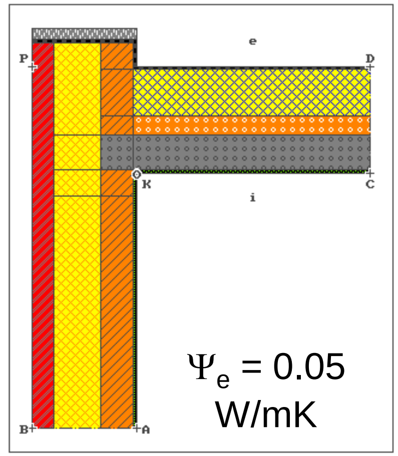
- Window
  - Sill
  - Lintel
  - Reveal
  - Dormer
- Flat roof
  - Parapet
  - Upper wall
  - Common wall
  - Canopy
- Wall
  - Exterior corner
  - Interior corner
  - Common wall
- Sloped roof
  - Eaves
  - Gable
  - Ridge
  - Upper wall
  - Bearing wall
  - Attic floor – exterior wall
- Floors
  - Ground floor – exterior wall
  - Ground floor – interior wall
  - Ground floor – door sill
  - Balcony floor –wall
  - Balcony floor – window
  - Floor above grade – exterior wall

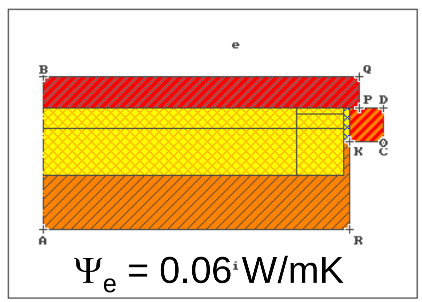
Thermal quality in constructional detailing



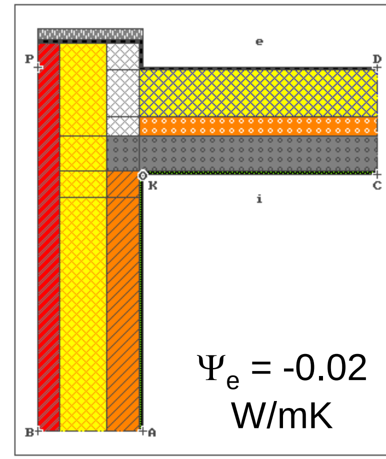


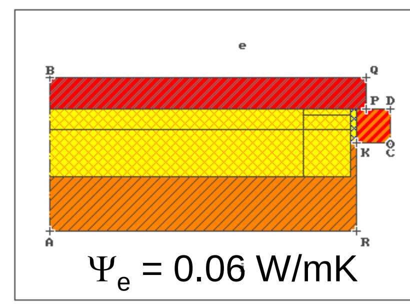
Business as usual:
Structural masonry intersects or intrudes insulation





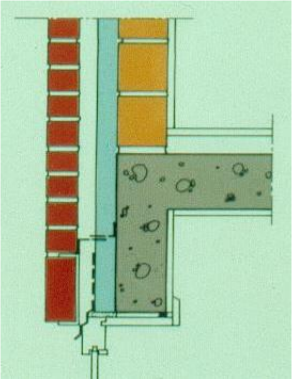
Standard:
No structural intrusions around windows

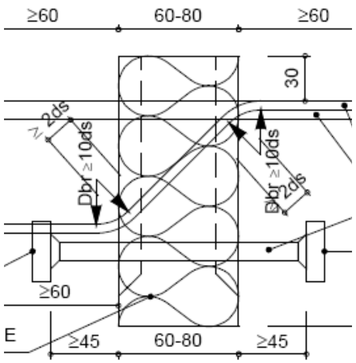




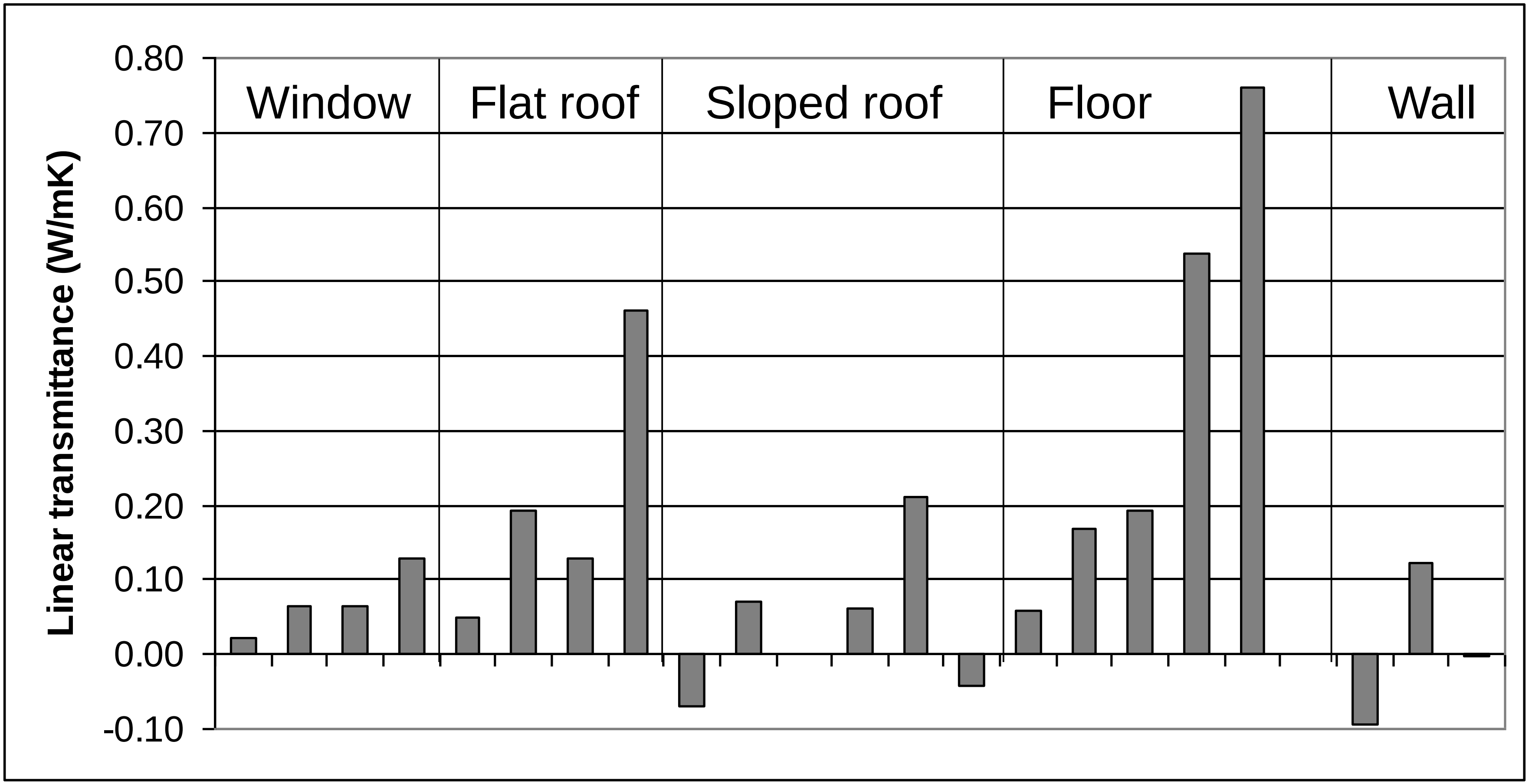
Thermal bridge avoidance:
Thermal breaks in structural masonry and concrete

Thermal bridge avoidance: thermal break technology

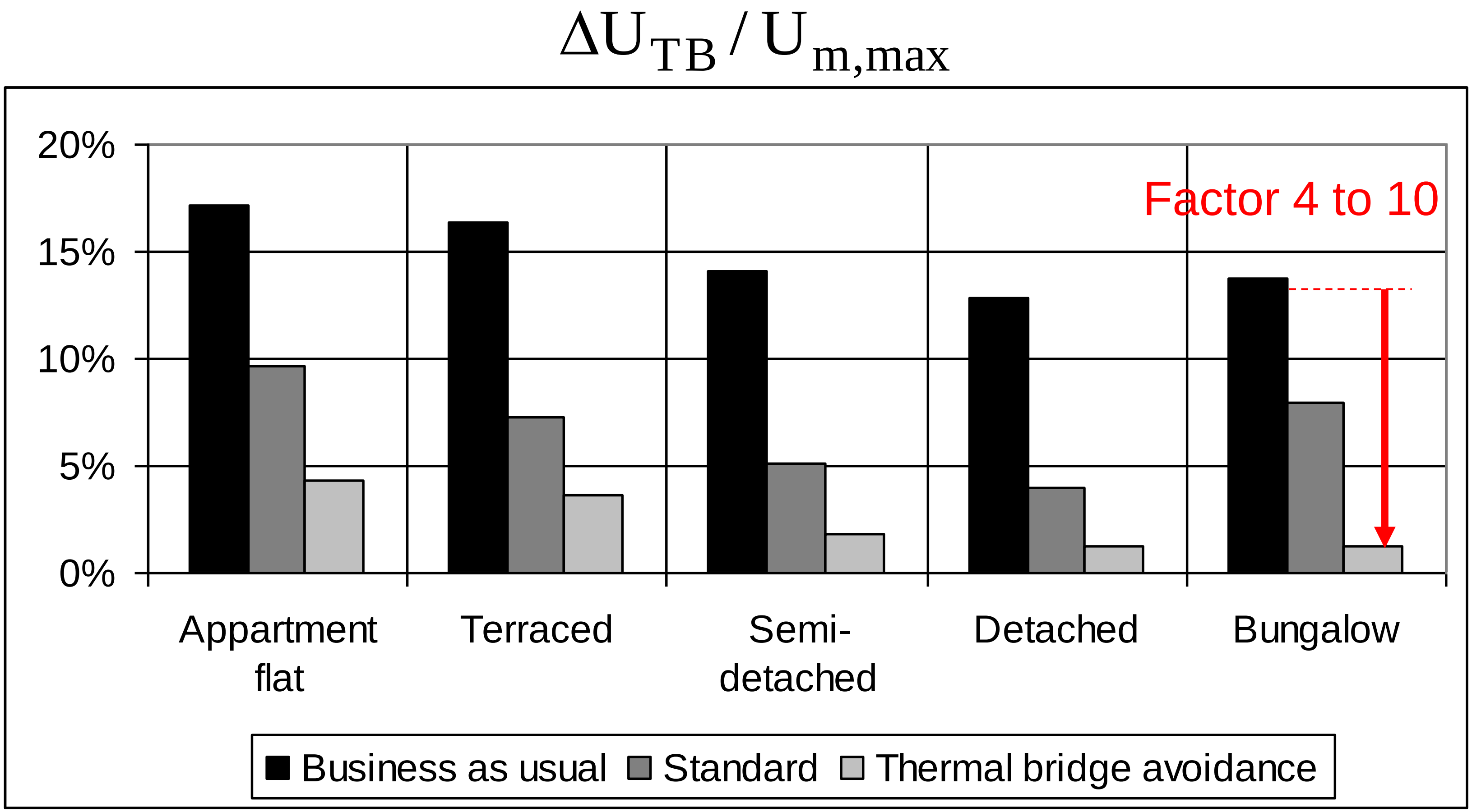




Linear thermal transmittance for 23 junctions
Standard detailing



Contribution of building junctions to average thermal transmittance



Proposed limits for linear thermal transmittance

Function of geometrical typology and technical feasibility

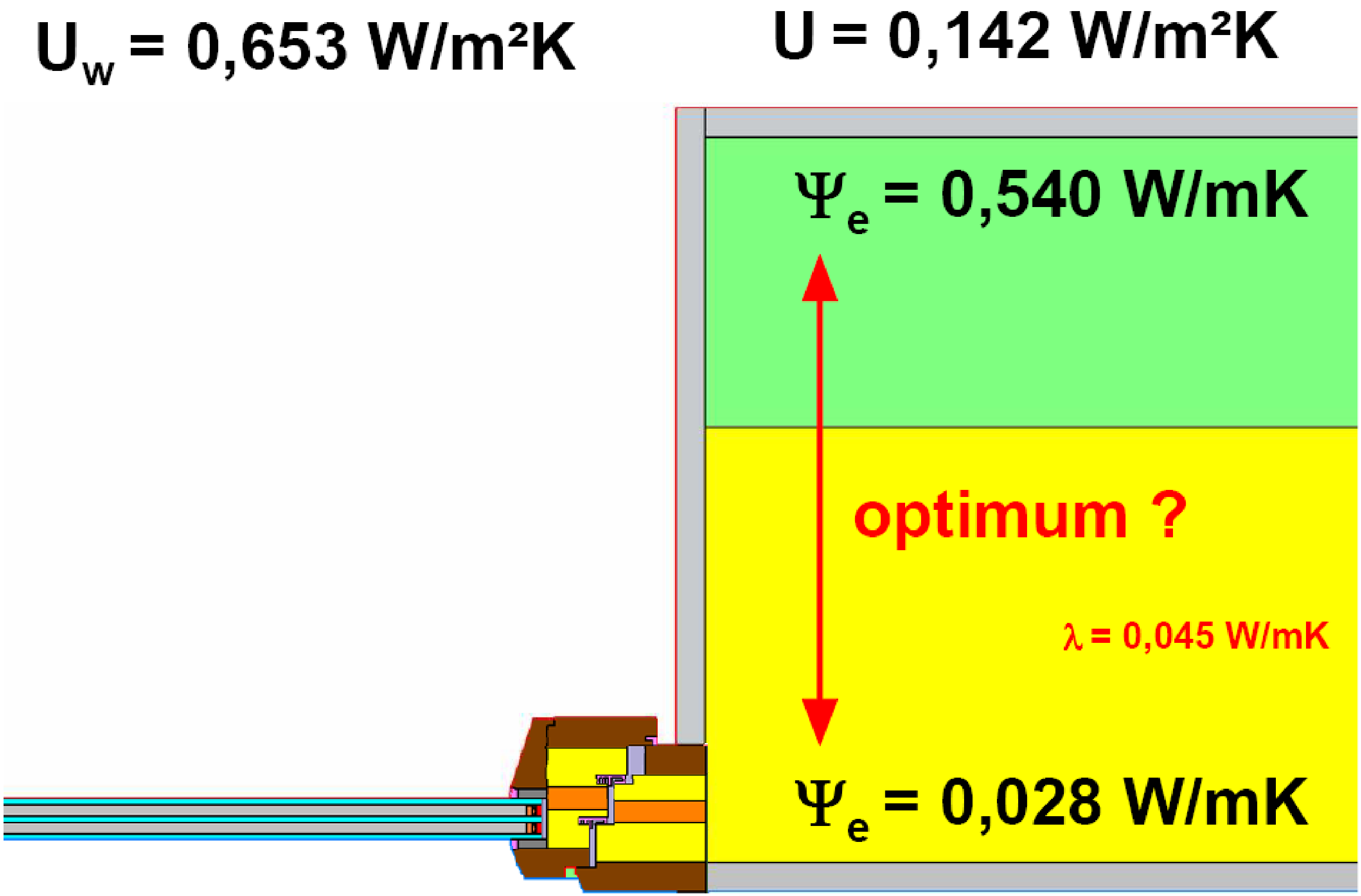
- Exterior corners $\Psi_e < 0.00$ W/mK
  - Roof eaves, overhanging floor
- Interior corners $\Psi_e < 0.15$ W/mK
  - Roof junction with upper wall
- Balconies and window junctions $\Psi_e < 0.10$ W/mK
- Other structural connections $\Psi_e < 0.05$ W/mK
  - Wall - ground floor, roof-bearing wall

Influence thermal bridges < 5%
of transmission heat loss requirement

Overview

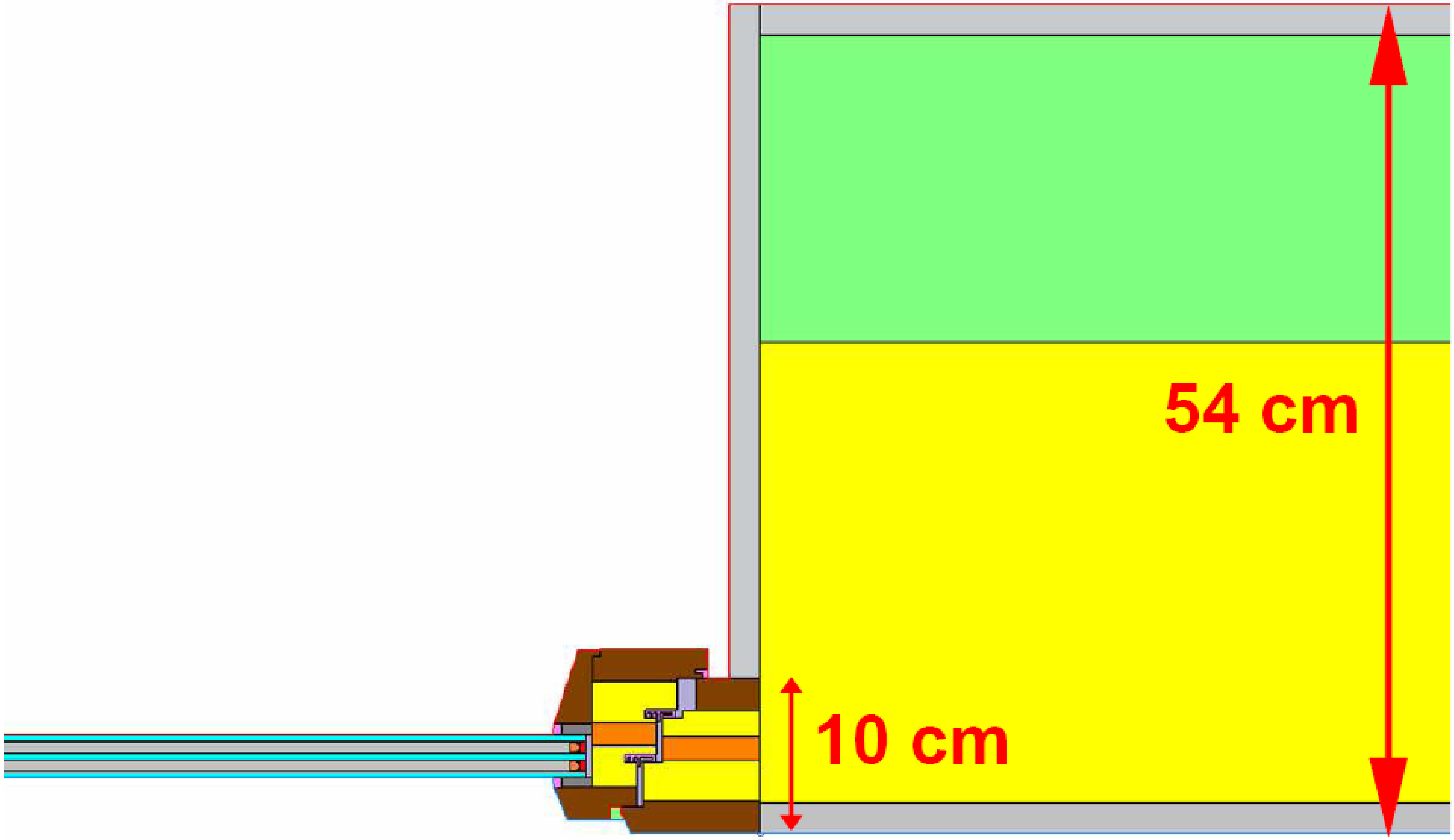
- Introduction:
  - Definition
  - Degradation
- Thermal performance criteria
- **Thermal optimization**
- Application in practice
- Steel construction

Thermal optimization



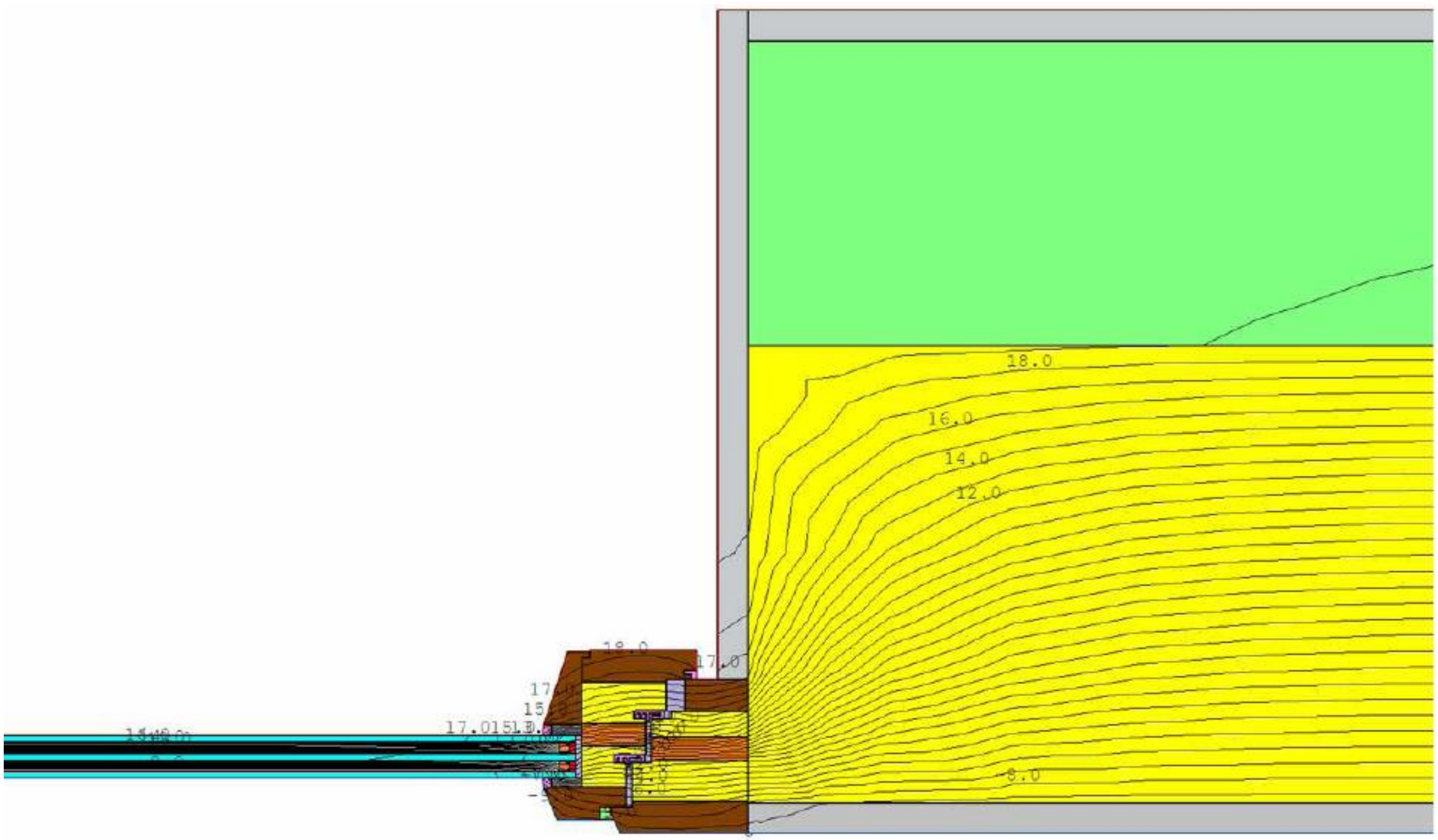
Thermal optimization

$\Psi_e = 0{,}028$ W/mK

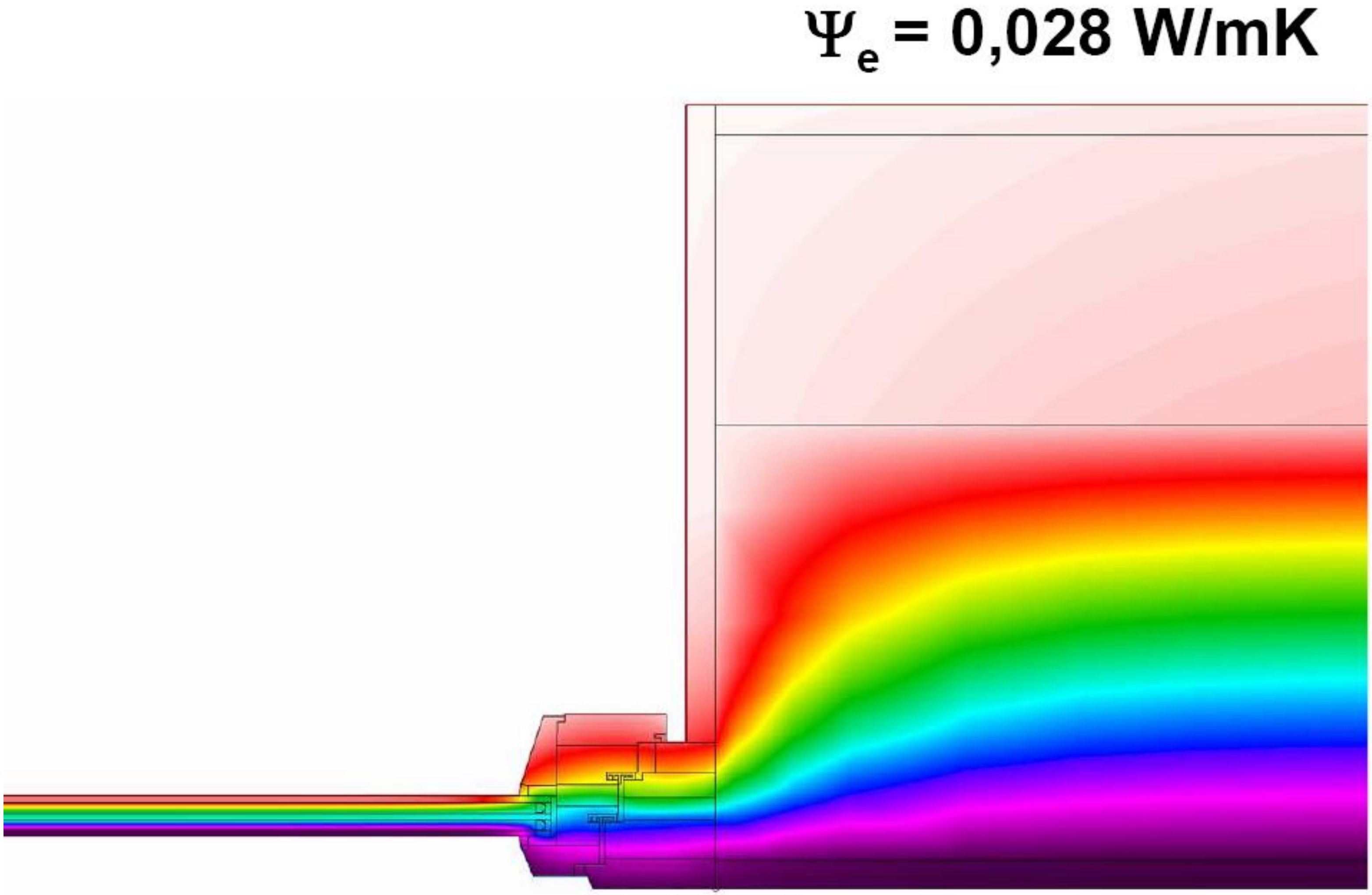


Thermal optimization

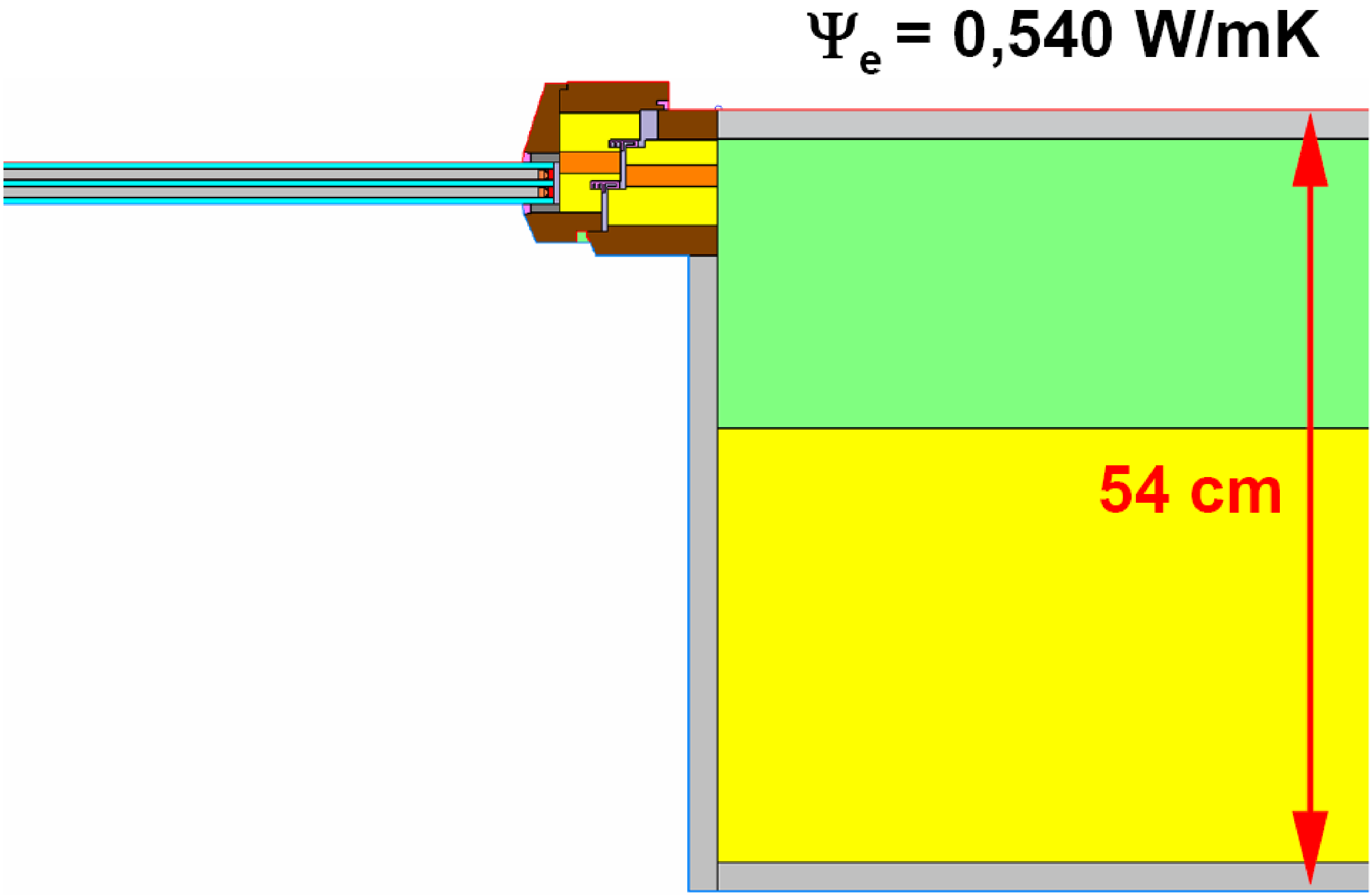
$$\Psi_e = 0{,}028\ \mathrm{W/mK}$$



Thermal optimization



Thermal optimization

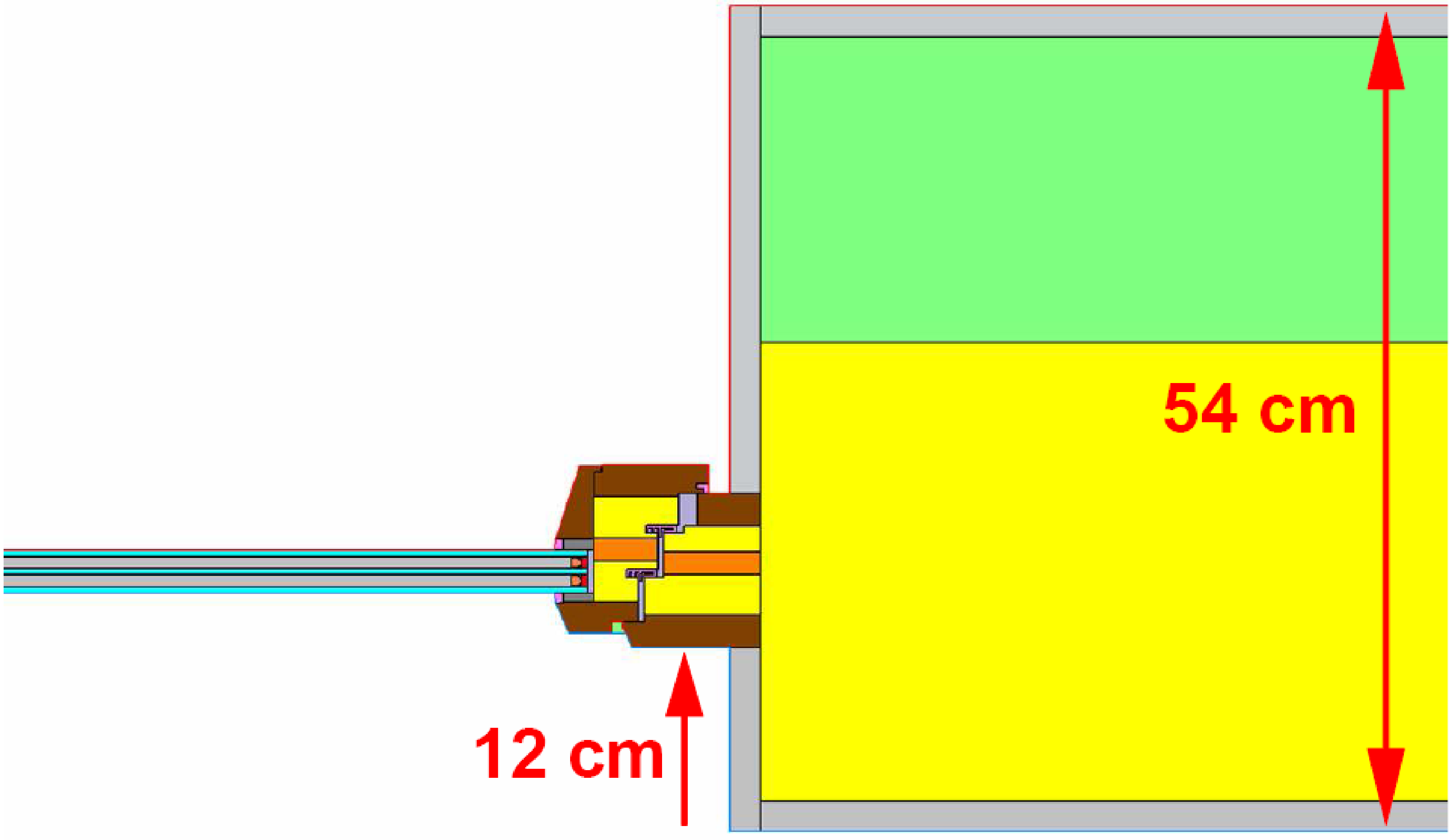


Thermal optimization

$\Psi_e = 0{,}540\ W/mK$

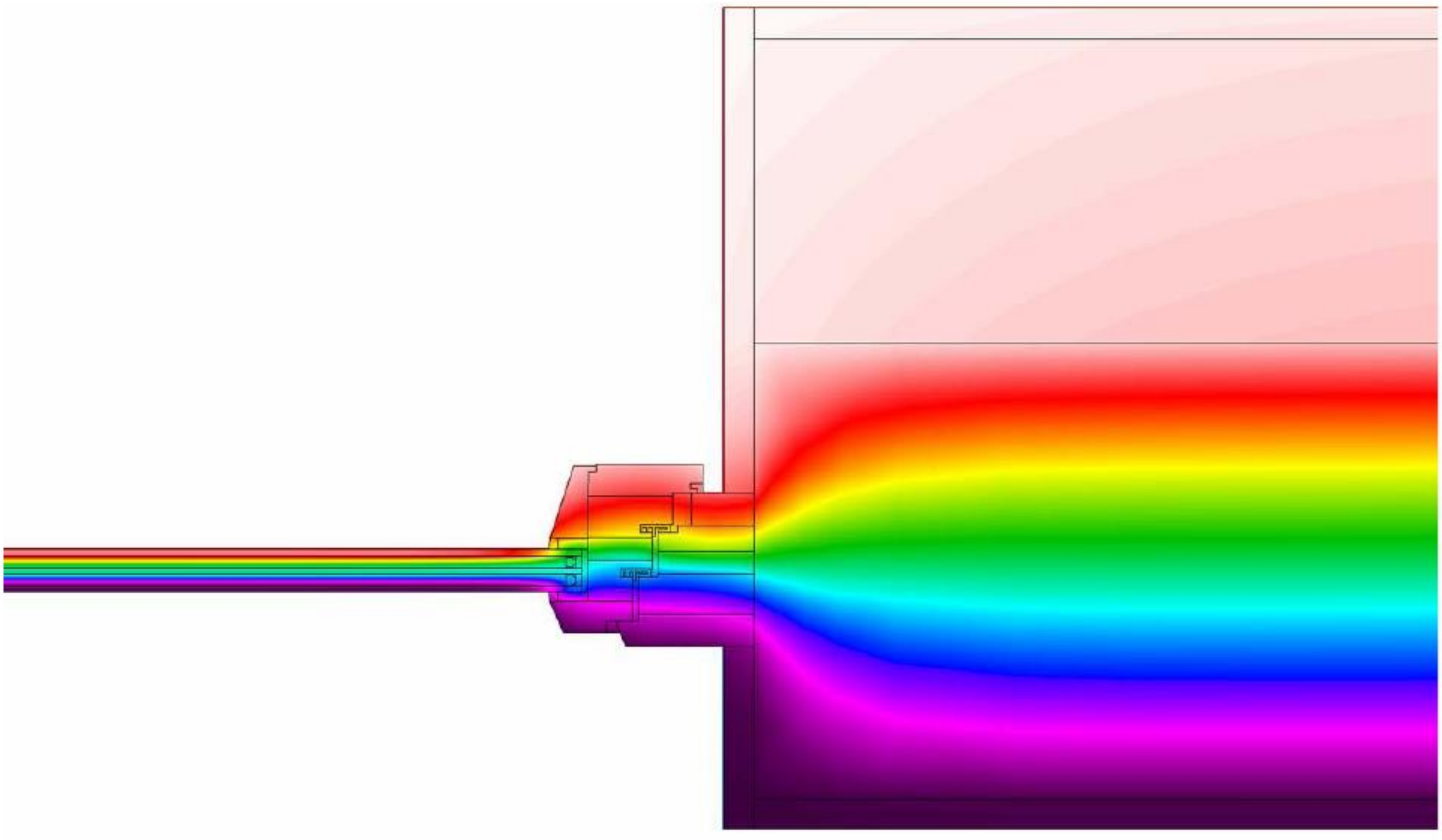
Thermal optimization

$\Psi_e = 0{,}012$ W/mK

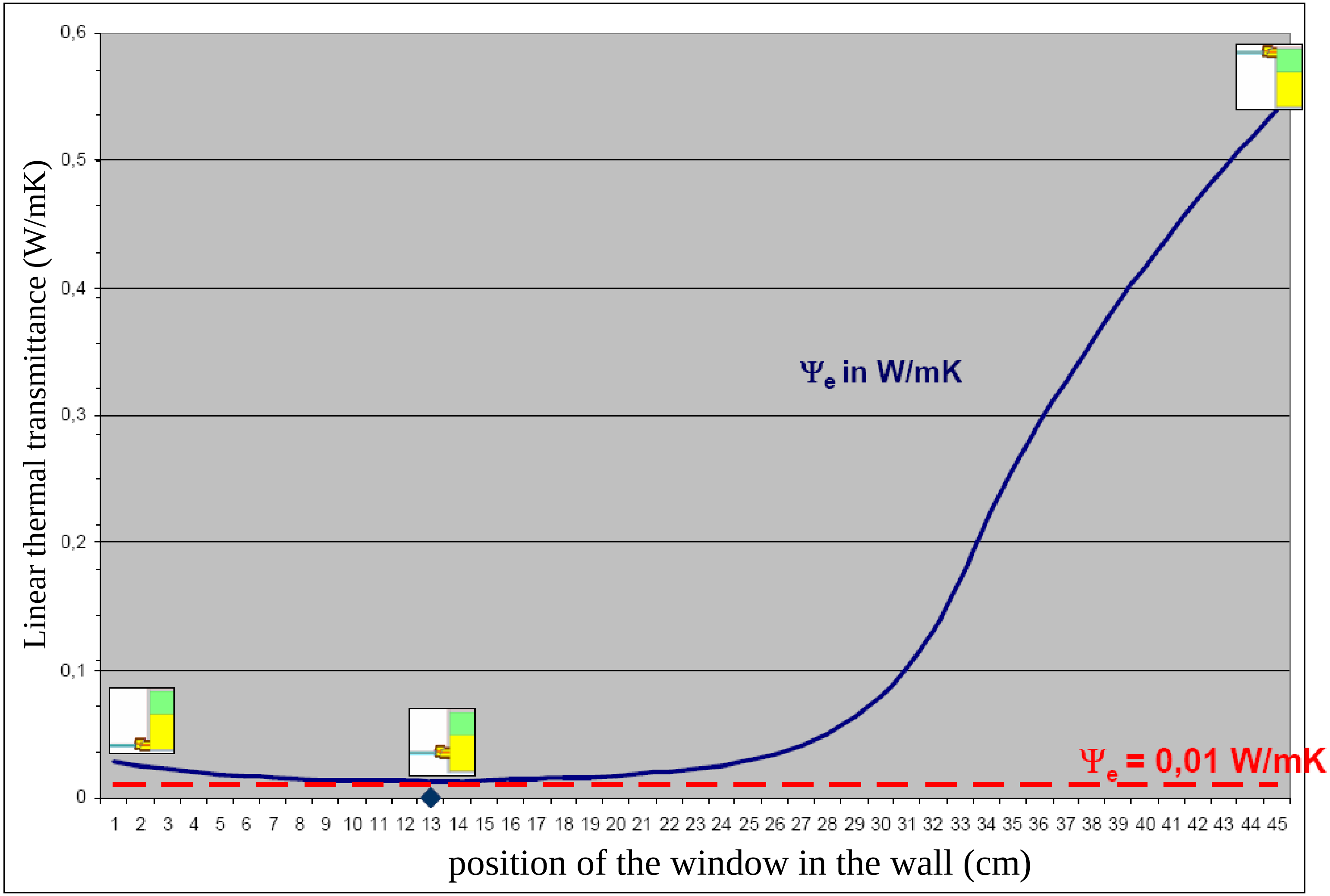


Thermal optimization

$\Psi_e = 0{,}012$ W/mK

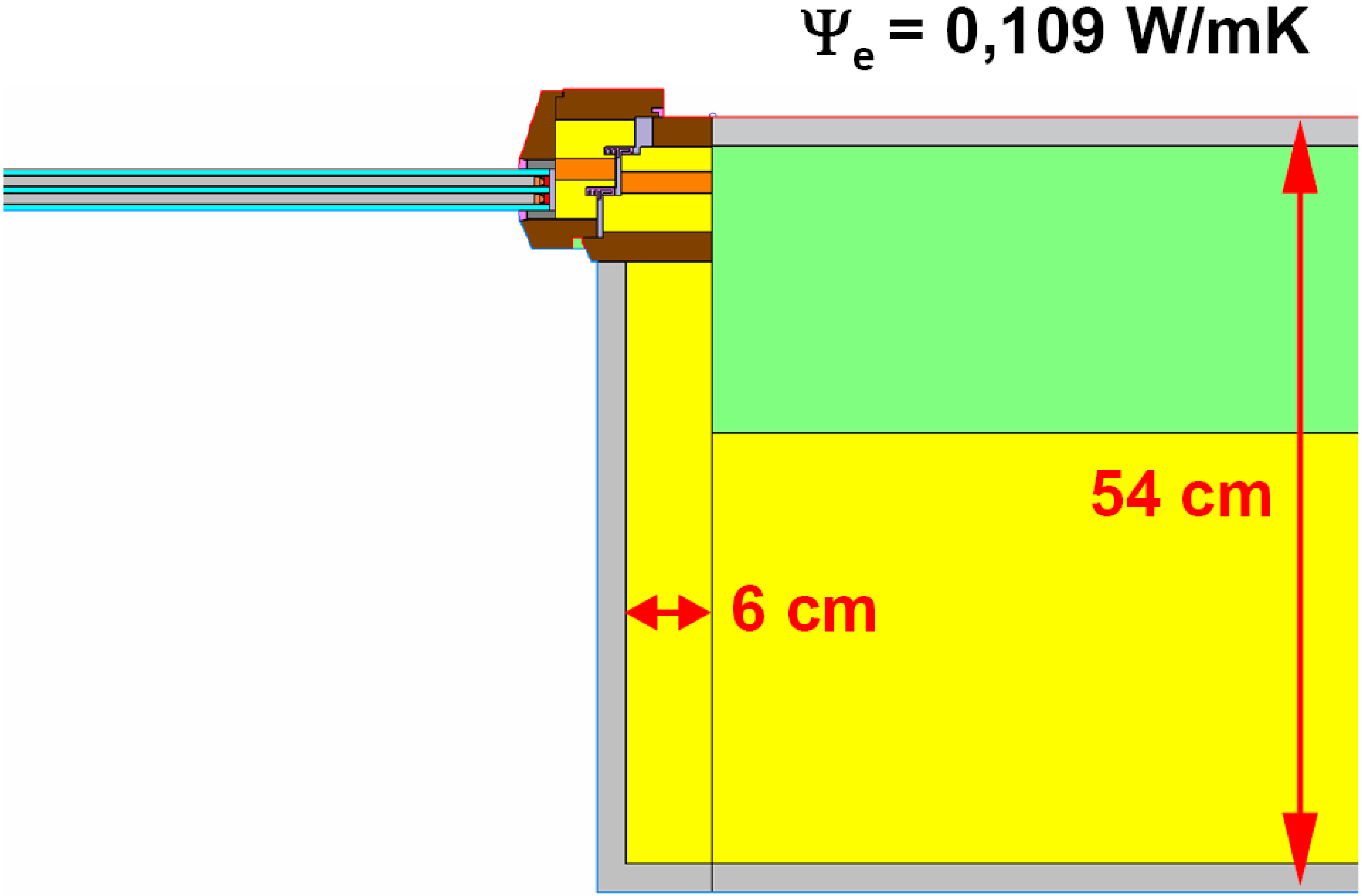


Thermal optimization



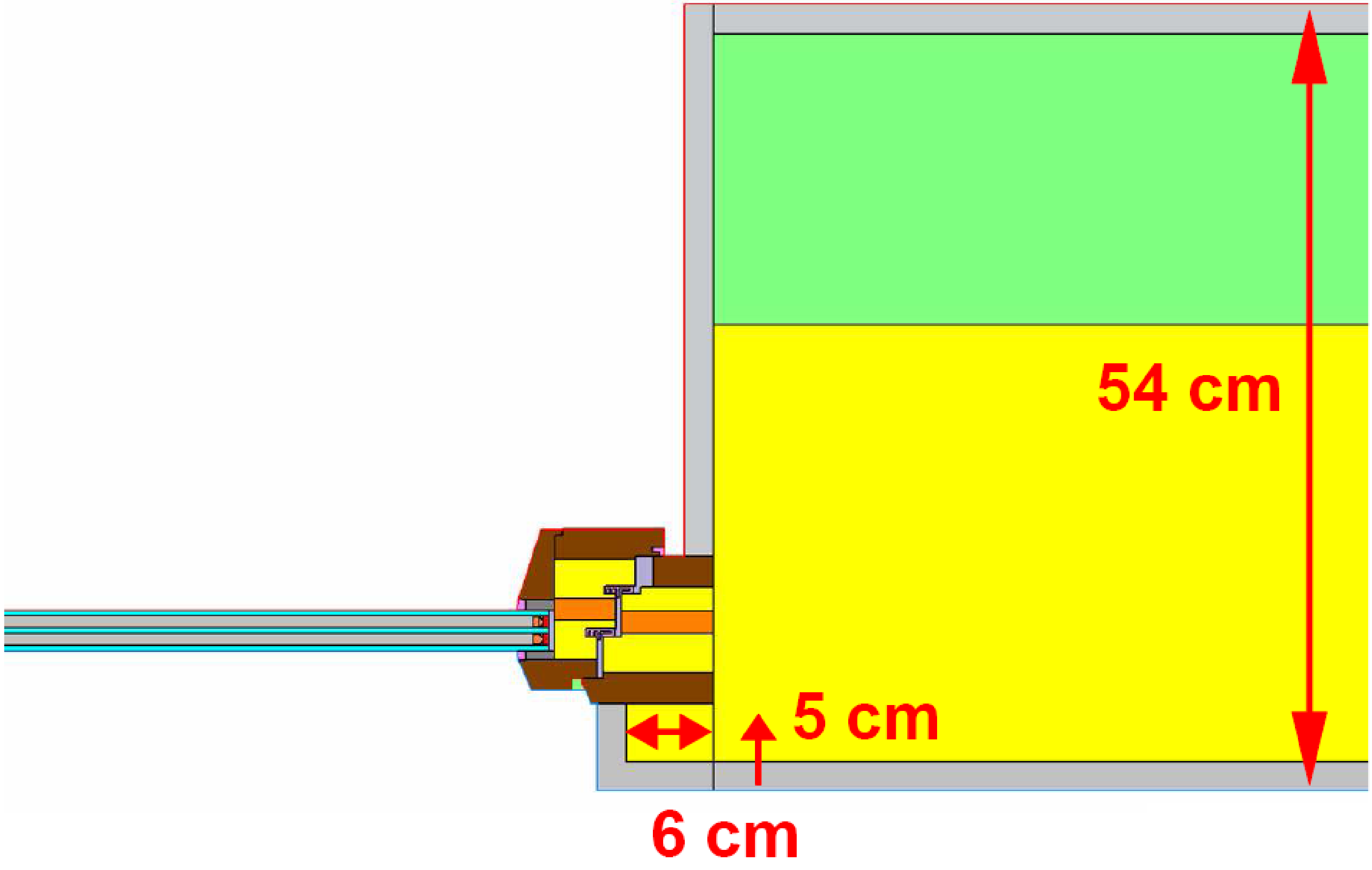
Passive house criterion

Thermal optimization

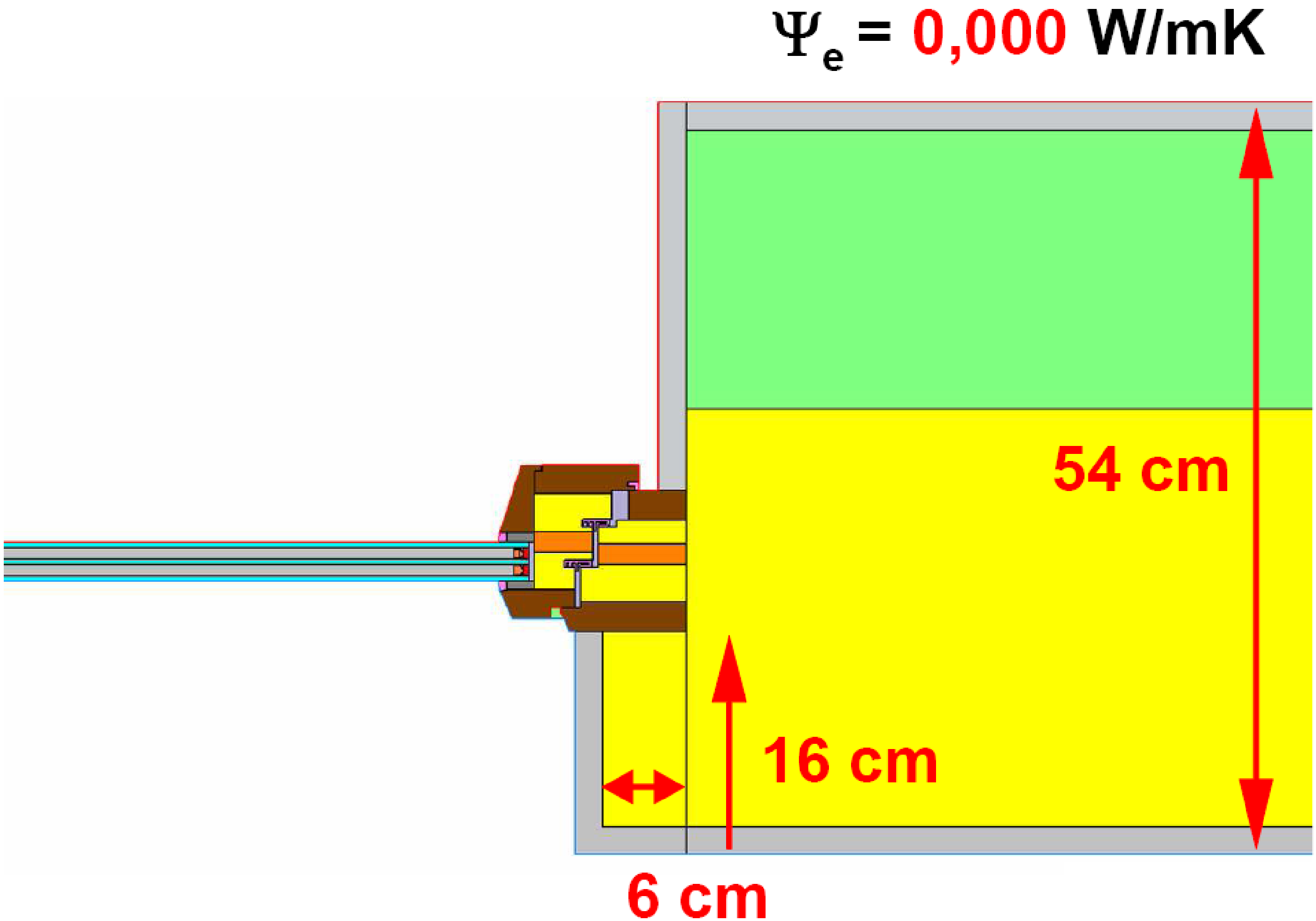


Thermal optimization

Ψ_e = 0,010 W/mK



Thermal optimization



Overview

- Introduction:
  - Definition
  - Degradation
- Thermal performance criteria
- Thermal optimization
- **Application in practice**
- Steel construction

Approaches to take thermal bridges into account (in force since 2011)

OPTION A
Detailed calculation

Project dependent addition

OPTION B
Method of EPB-accepted junctions
'PRAGMATIC APPROACH'

- EPB-accepted junctions: ***Fixed addition ≈ +7%***

+

- non -EPB-accepted junctions: ***Varying addition***

OPTION C
'Penalisation method'

Fixed addition ≈ +25%

OPTION A

ALL junctions need to be individually assessed and reported

→ *EACH linear junction: Ψ_e (W/mK) and length l*
→ *EACH pointwise junction: χ_e (W/K) and number*

$$H_T^{junctions} = \sum_k l_k b_k \psi_{e,k} + \sum_l b_l \chi_{e,l} \qquad \left[\frac{W}{K}\right]$$

- ❑ by means of numerical calculations
  - ✓ according to EN ISO 10211 with national specifications
- ❑ by means of default values

DEFAULT VALUES

FUNCTION JUNCTION TYPE

Linear junctions	
Junction without thermal break and structural connection in metal or reinforced concrete	$0.90 + \Psi_{e,lim}$ W/m.K
Junction with thermal break and structural pointwise connections in metal	$0.40 + \Psi_{e,lim}$ W/m.K
Others	$0.15 + \Psi_{e,lim}$ W/m.K
Pointwise junctions	
Interruption of thermal insulation by metal elements (z = largest size of intersection, in m)	4.7*z + 0.03 W/K
Interruption of thermal insulation by non-metalic elements (A = section of interruption, in m^2)	3.8*A + 0.1 W/K

→ Conservative values

OPTION B

The junctions are subdivided in 2 categories, each with another influence on the transmission heat loss

- **EPB-accepted junctions**

  = *junctions with limited thermal bridge effects*

  → *are taken into account at building level*
  →*no effort to report junction geometry and thermal transmittance*

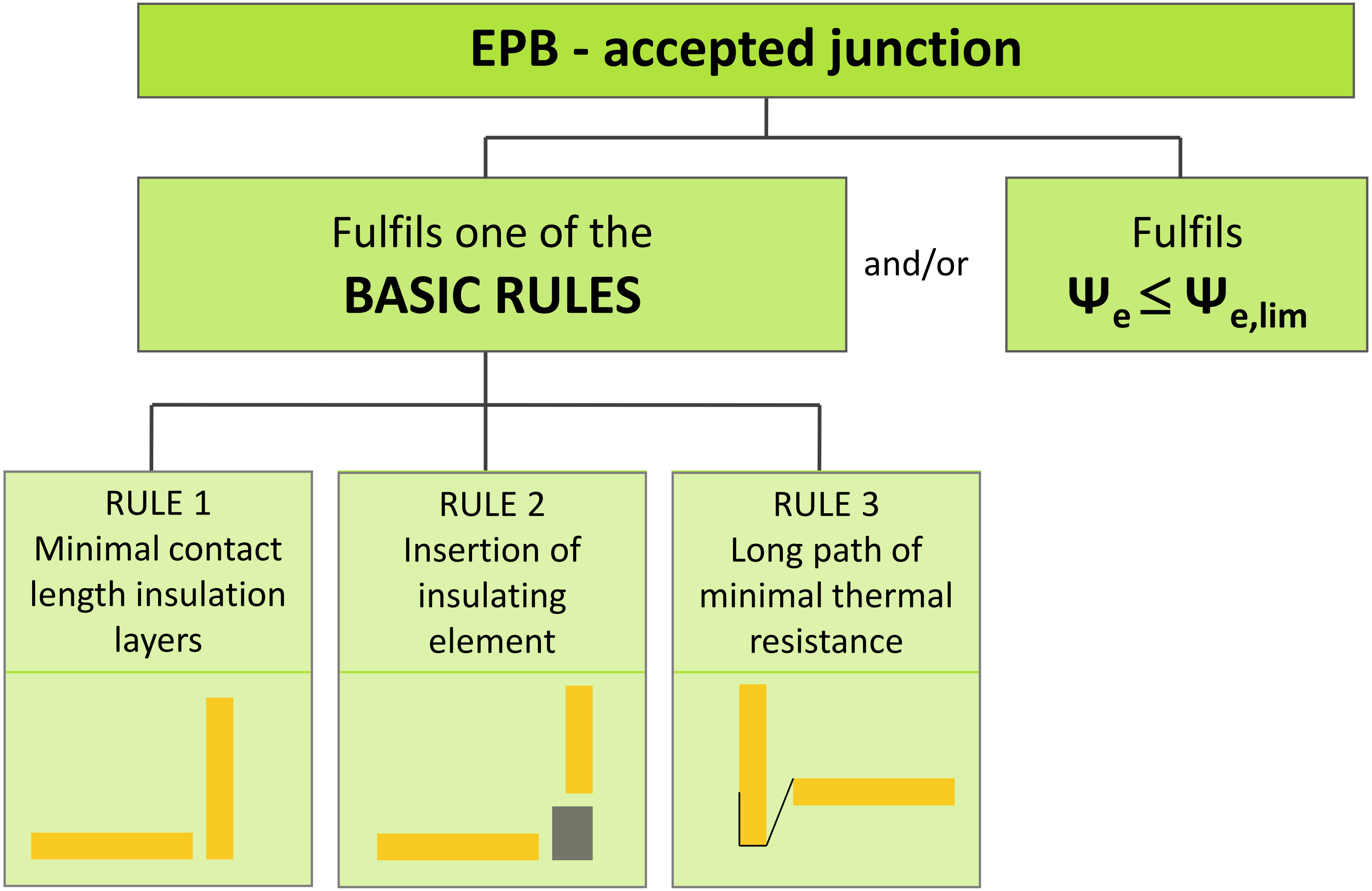
  → **Fixed addition (small)**

- **non-EPB-accepted junctions**

  = *thermal bridges that are not solved*

  → *are taken into account for each building junction using calculated or default values (see OPTION A)*

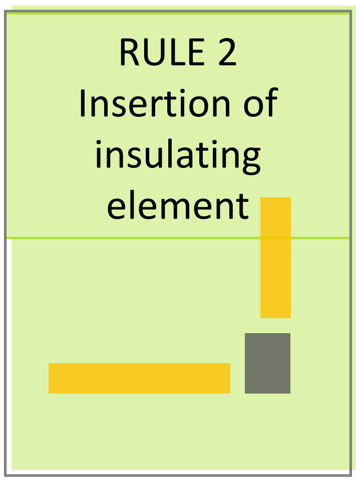
  → **Varying addition**


EPB - accepted junction
Fulfils one of the
BASIC RULES
and/or
Fulfils
$\Psi_e \leq \Psi_{e,lim}$
RULE 1
Minimal contact length insulation layers
RULE 2
Insertion of insulating element
RULE 3
Long path of minimal thermal resistance

Basic rule 1: minimal contact length
Examples of performance based specifications

RULE 1
Minimal contact length insulation layers

Performance based rules are easy to apply and can be checked visually



- $\lambda \leq 0.2$ W/mK

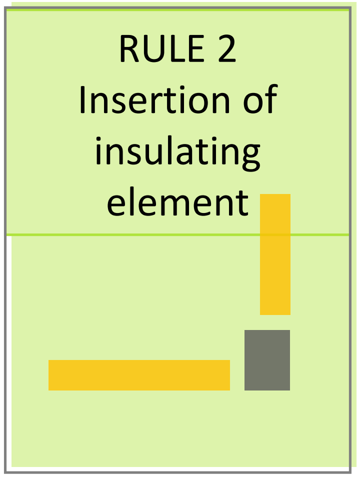
AND

- $R > \min(R_1/2, R_2/2, 2)$

AND

- Minimal contact length

Performance based rules are easy to apply and can be checked visually



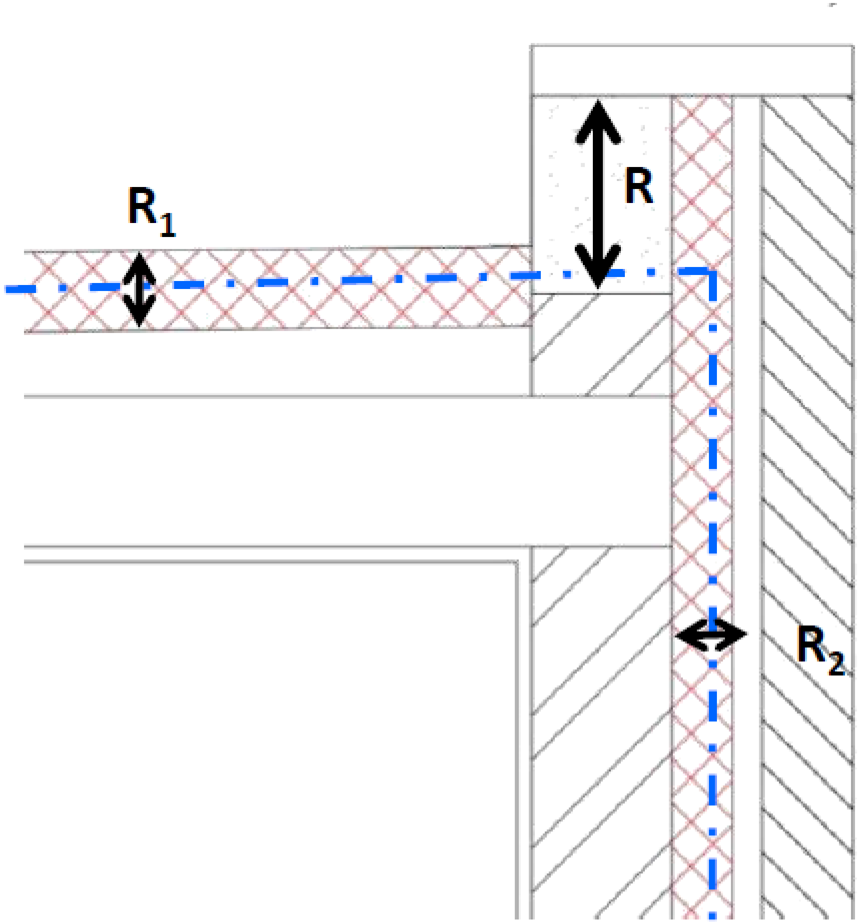
- λ ≤ 0.2 W/mK

AND

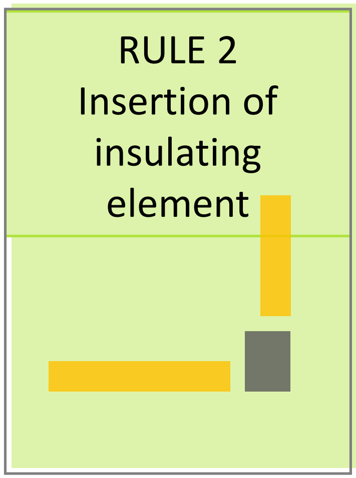
- $R > \min(R_1/2, R_2/2, 2)$

AND

- Minimal contact length

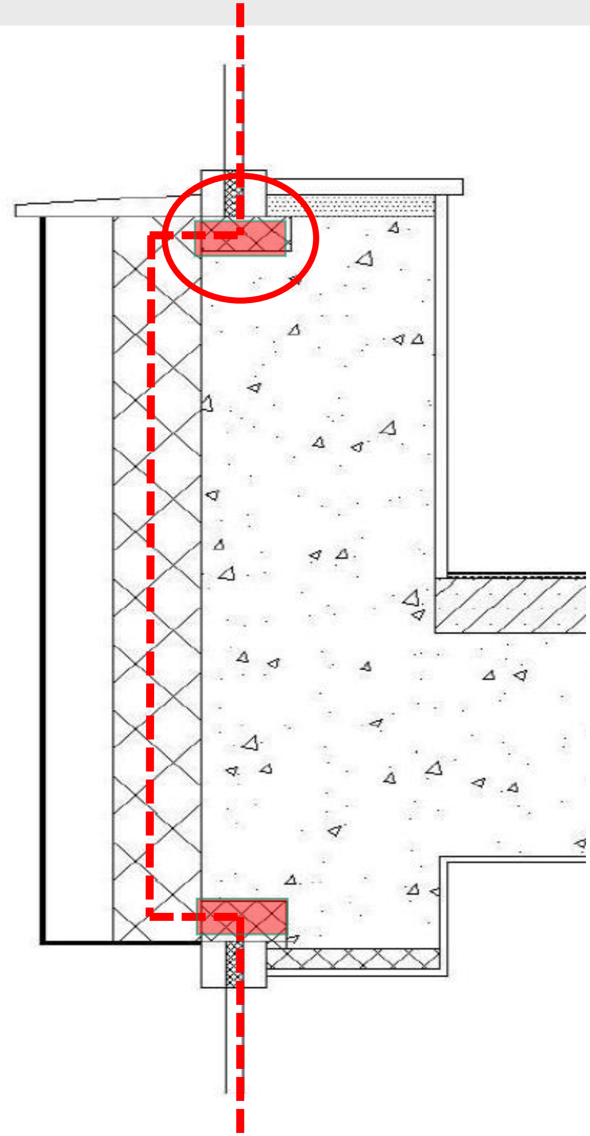


Performance based rules are easy to apply and can be checked visually



Check R in

2 directions



- $\lambda \leq 0.2$ W/mK

AND

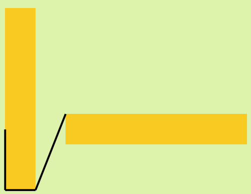
- $R > \min(R_1/2, R_2/2, 2)$

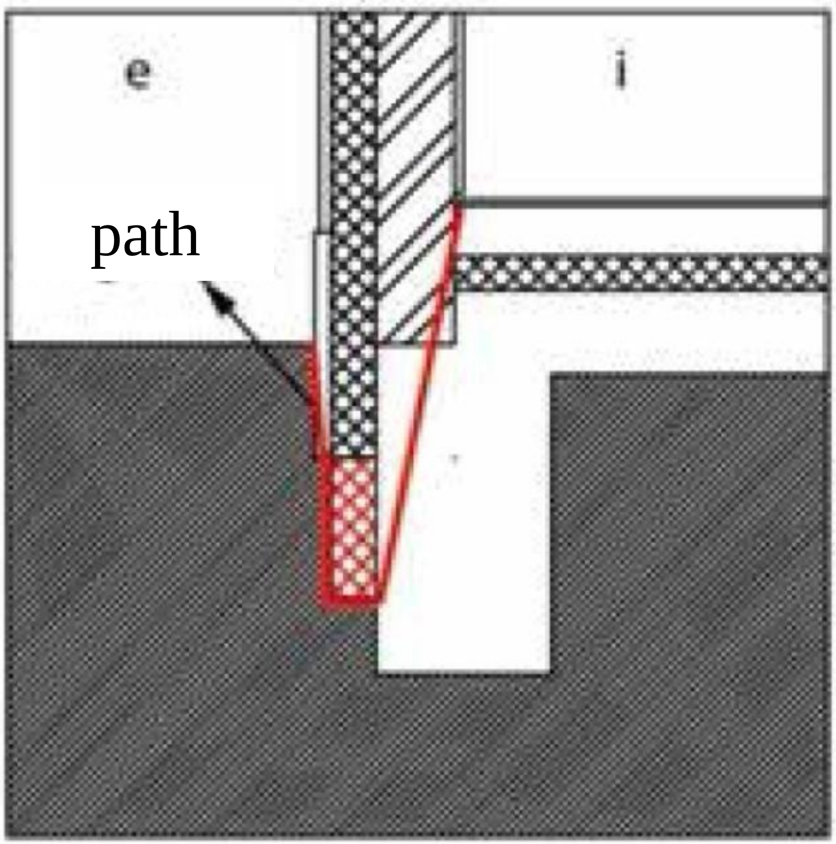
AND

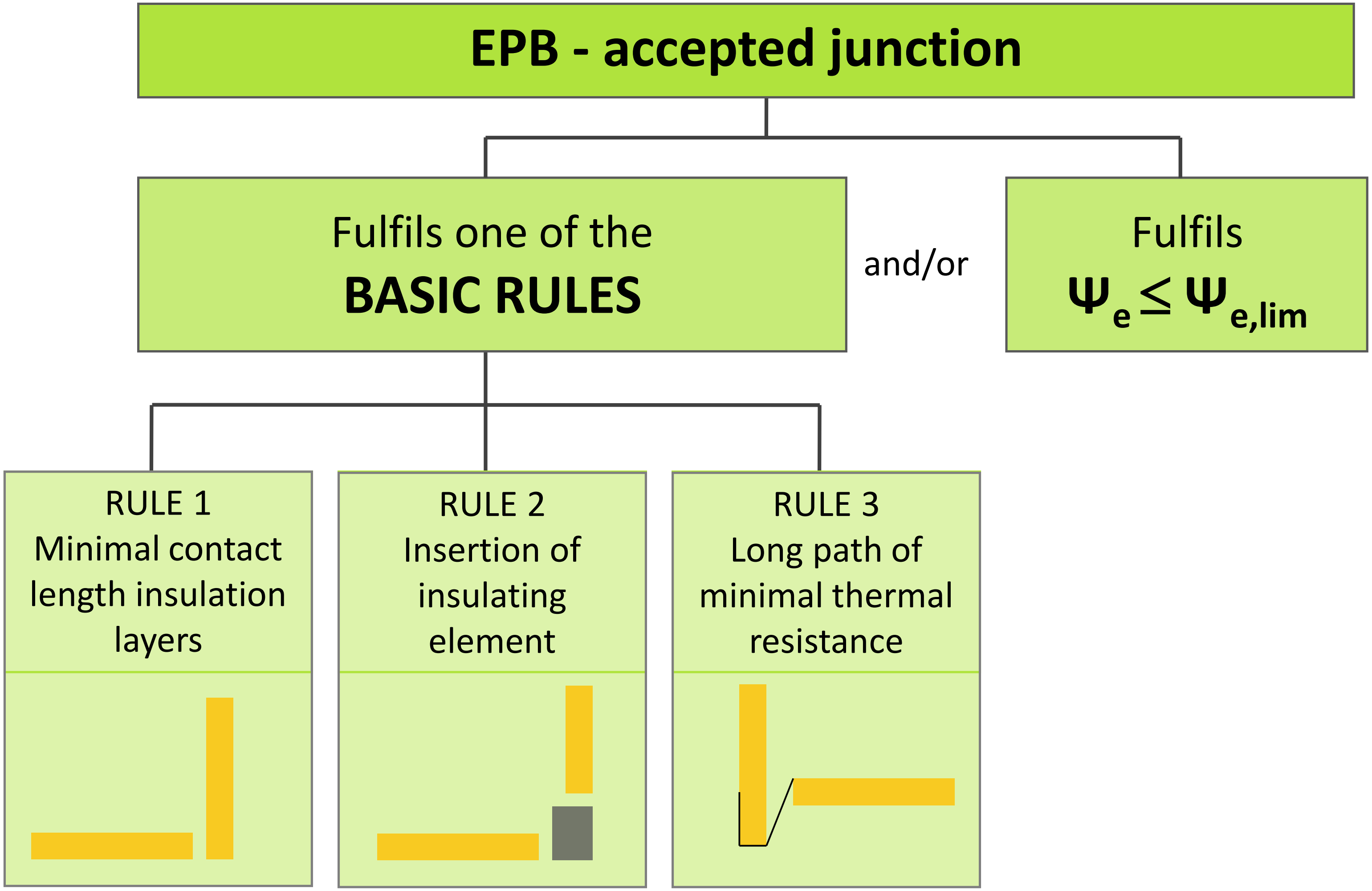
- Minimal contact length

Performance based rules are easy to apply and can be checked visually

RULE 3
Long path of minimal thermal resistance






EPB - accepted junction
Fulfils one of the
BASIC RULES
and/or
Fulfils
$\Psi_e \leq \Psi_{e,lim}$
RULE 1
Minimal contact length insulation layers
RULE 2
Insertion of insulating element
RULE 3
Long path of minimal thermal resistance

Limiting values for linear thermal transmittance $\Psi_e \leq \Psi_{e,lim}$

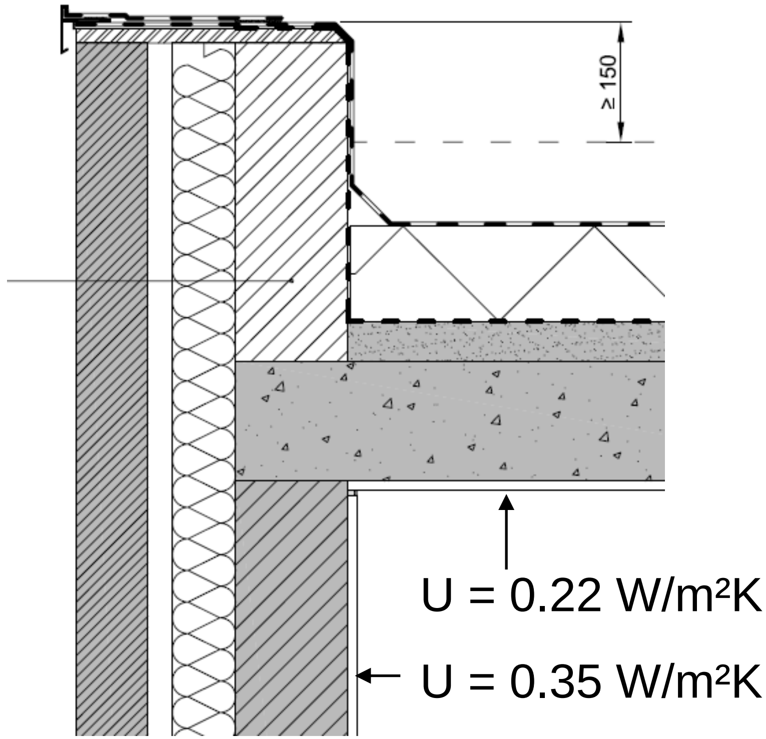
Function of geometrical typology and technical feasibility

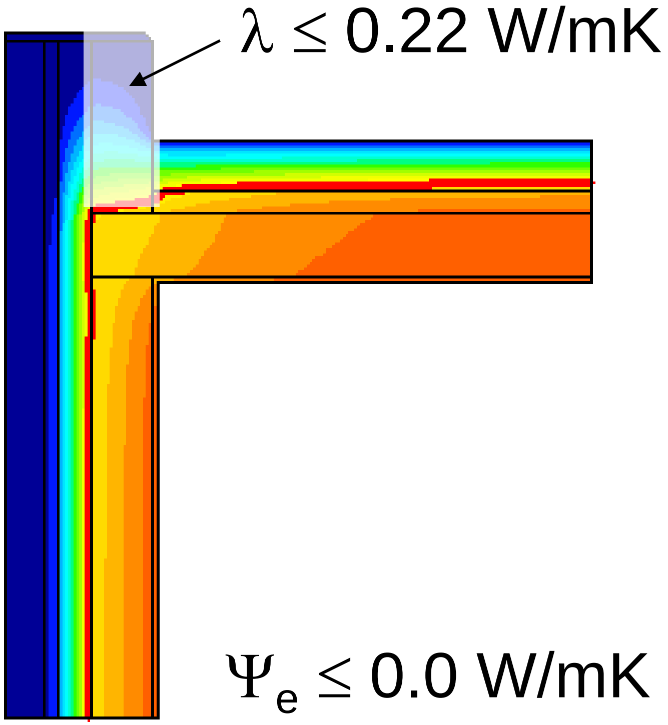
- Exterior corners $\Psi_e < 0.00$ W/mK
  - Roof eaves, overhanging floor
- Interior corners $\Psi_e < 0.15$ W/mK
  - Roof junction with upper wall
- Balconies and window-wall junctions $\Psi_e < 0.10$ W/mK
- Other structural connections $\Psi_e < 0.05$ W/mK
  - Wall - ground floor, roof-bearing wall

Building manufacturing companies have developed product documentation and reporting tools based on the EPB-accepted junctions method.

Application of limiting values

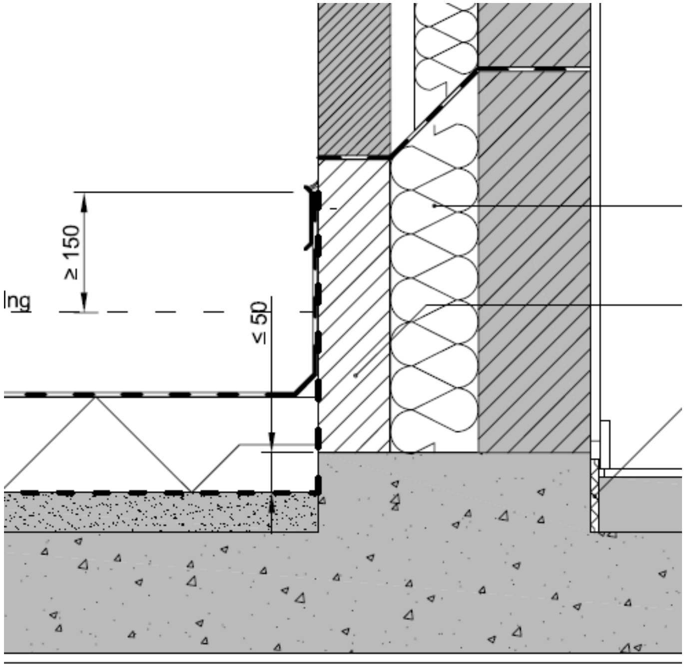
Adoption of improved solutions by construction industry

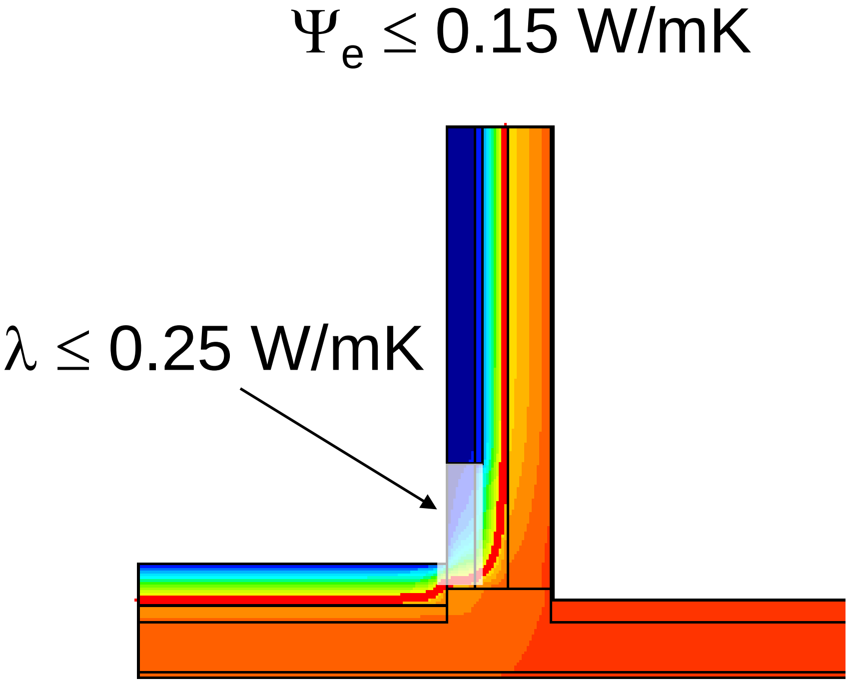




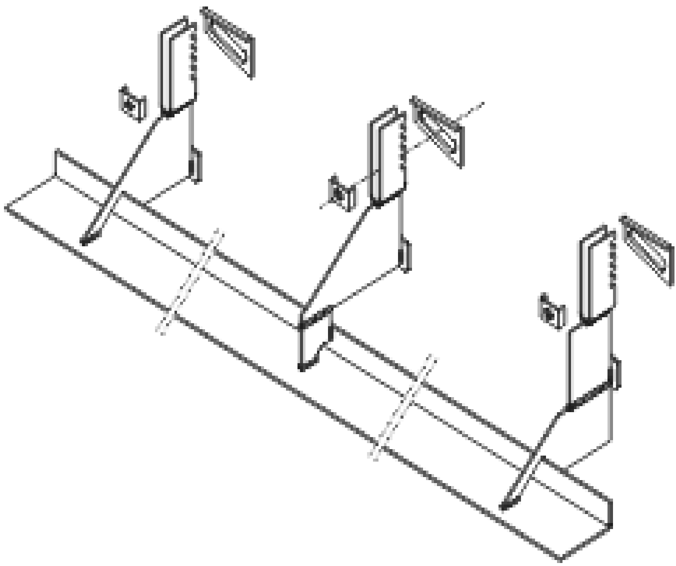
Application of limiting values

Adoption of improved solutions by construction industry



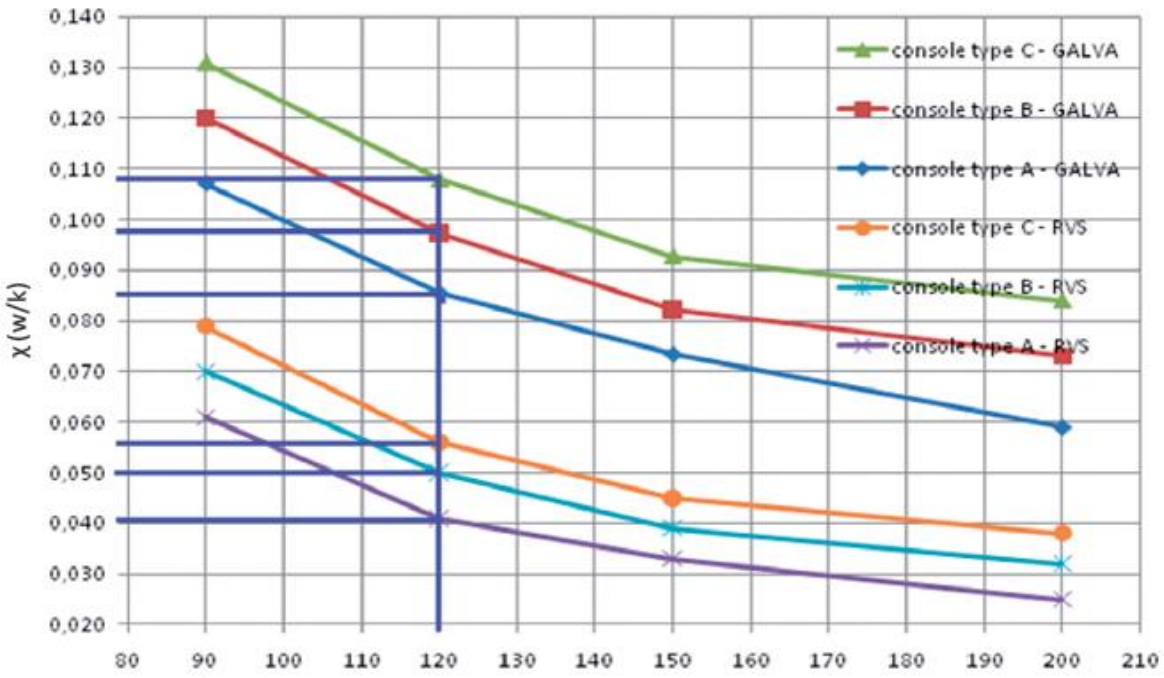


Product documentation example
Steel connections for lintel supports

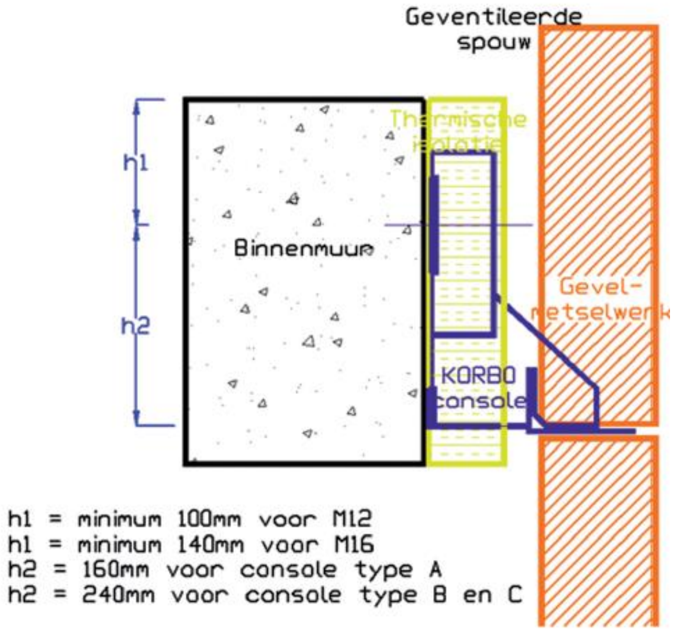


Difference between steel and stainless steel

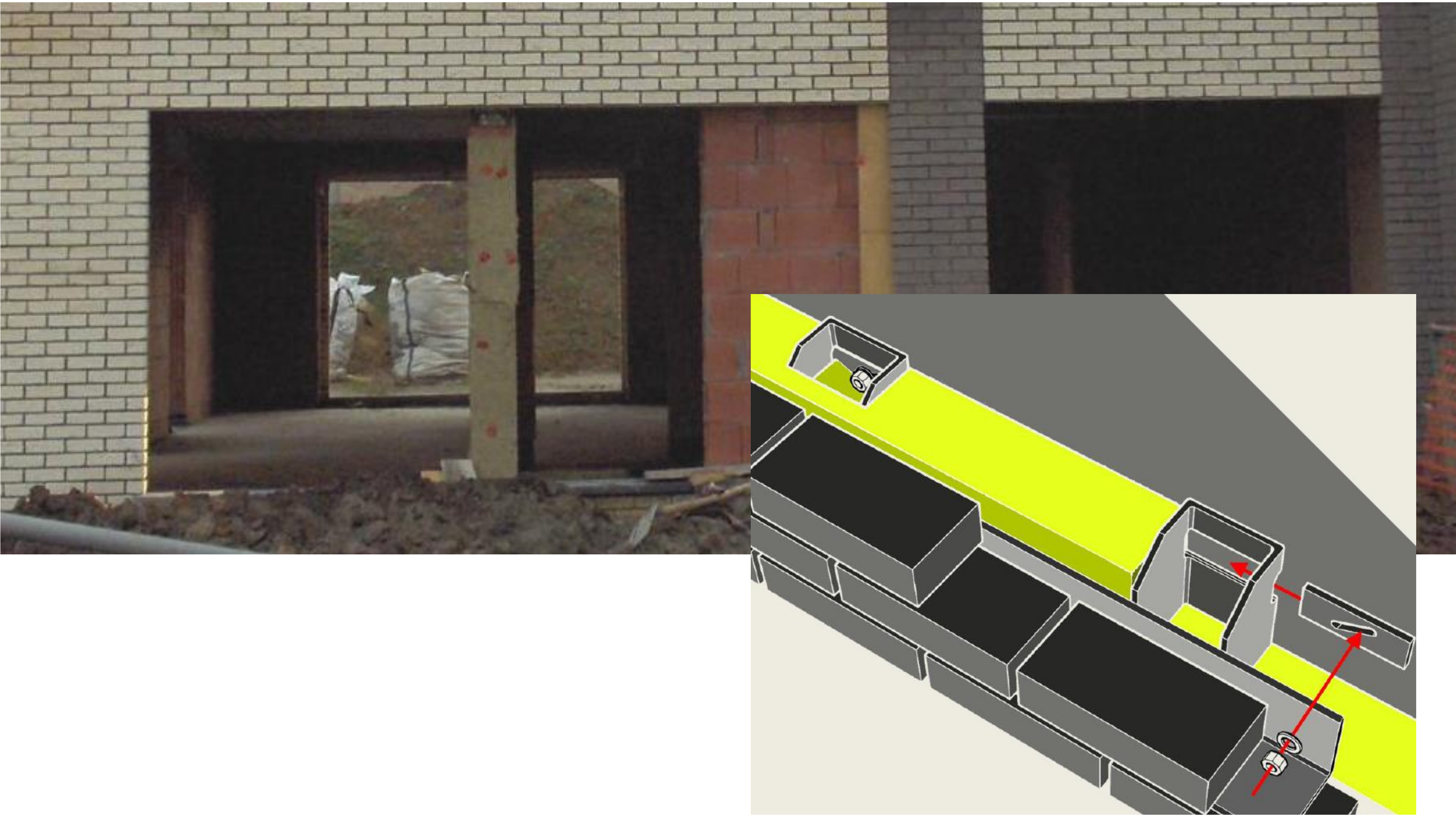
(GALVA) (RVS)



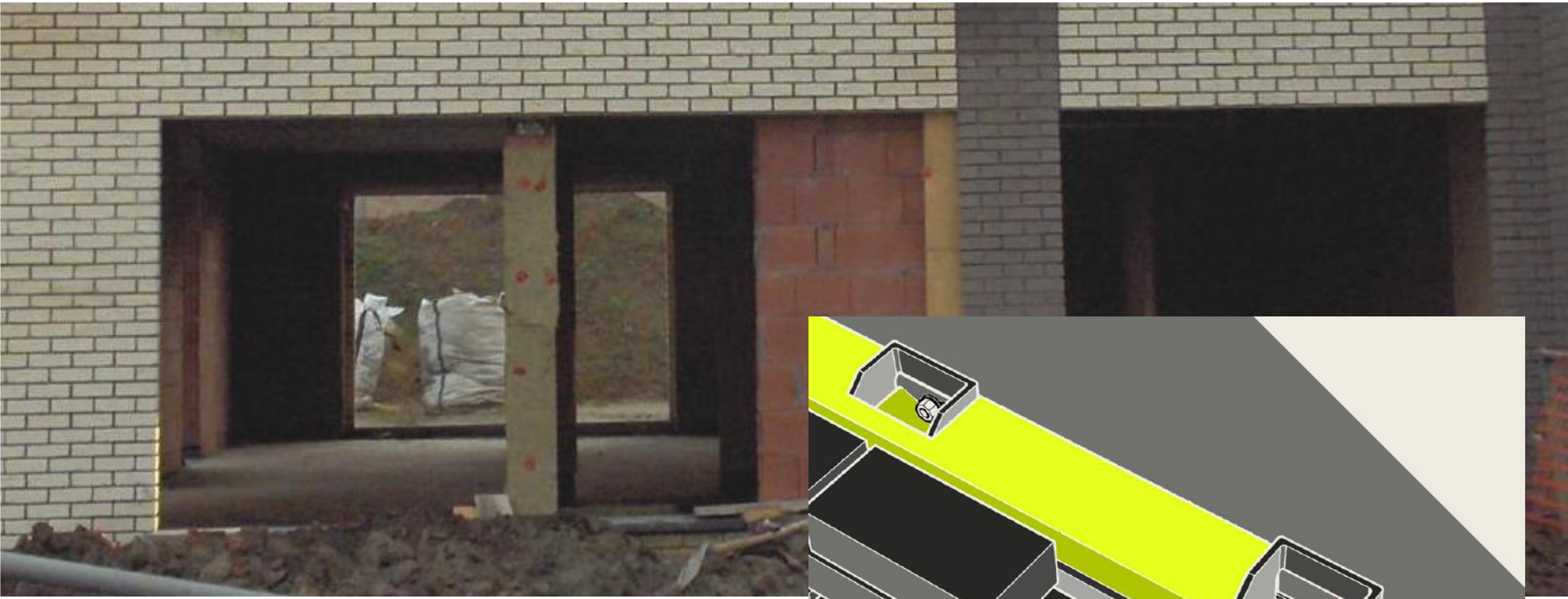
width insulation + cavity (mm)

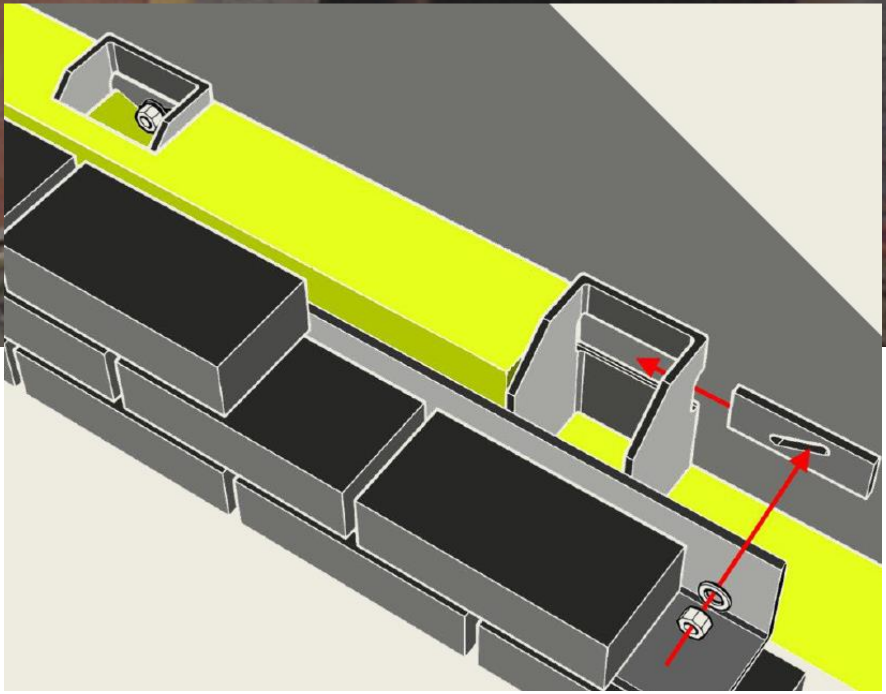


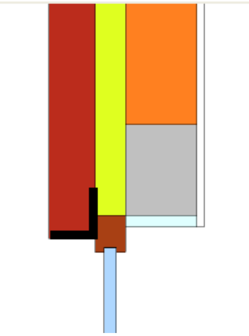
Sometimes combinations



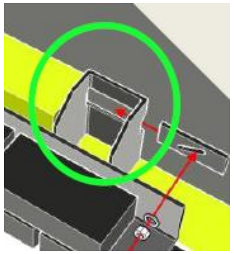
Sometimes combinations







+



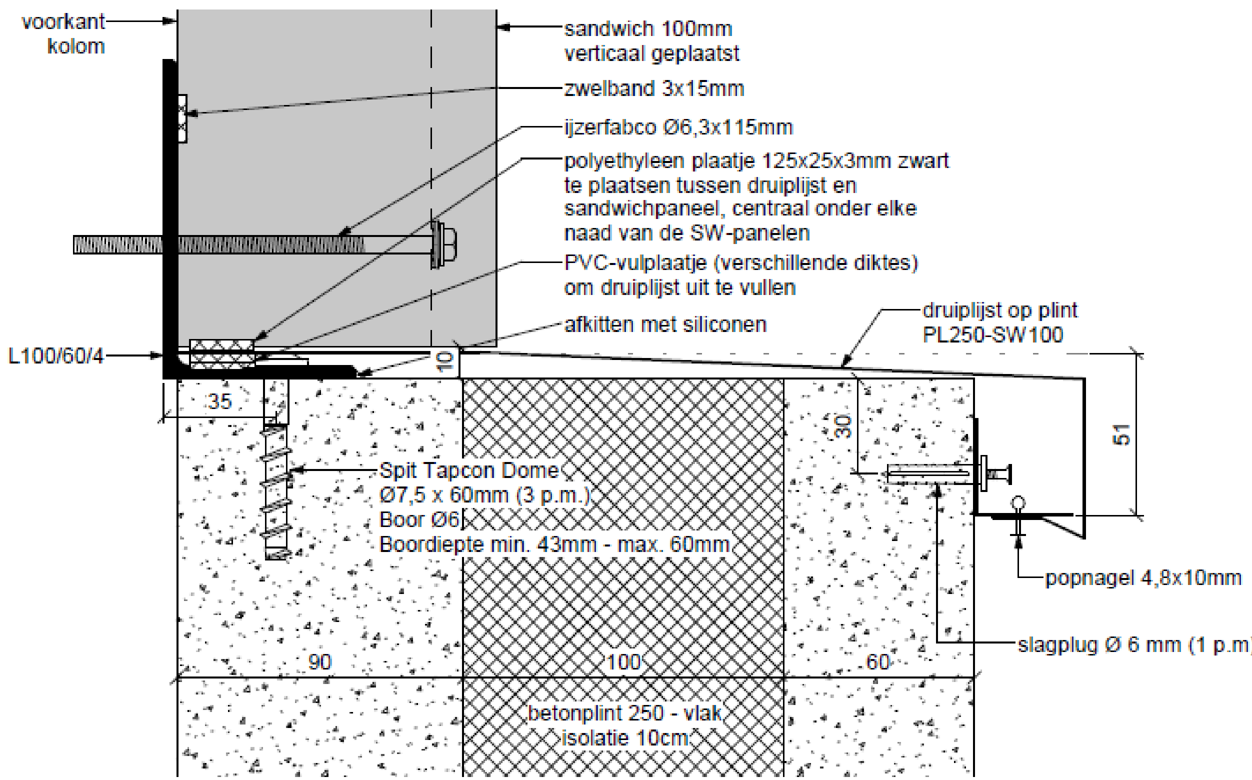
Linear + point thermal bridges

Overview

- Introduction:
  - Definition
  - Degradation
- Thermal performance criteria
- Thermal optimization
- Application in practice
- **Steel construction**

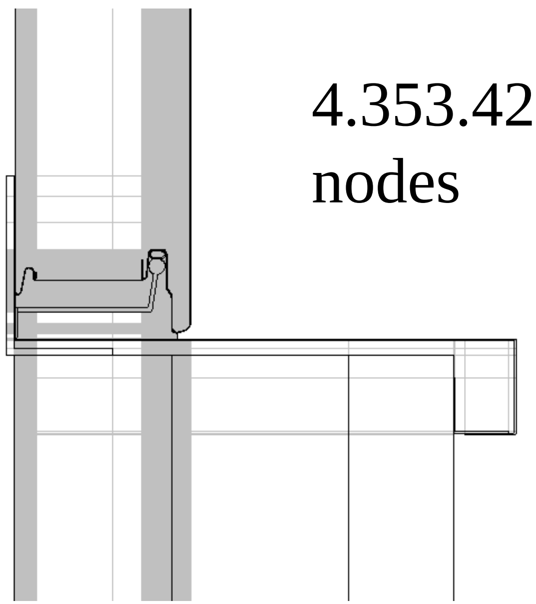
Numerical simulations – geometrical complexity

- ISO 10211: when λ > 3 W/mK, no simplification allowed
- Grid of 0.1mm required
- Non-orthogonal parts increase # nodes

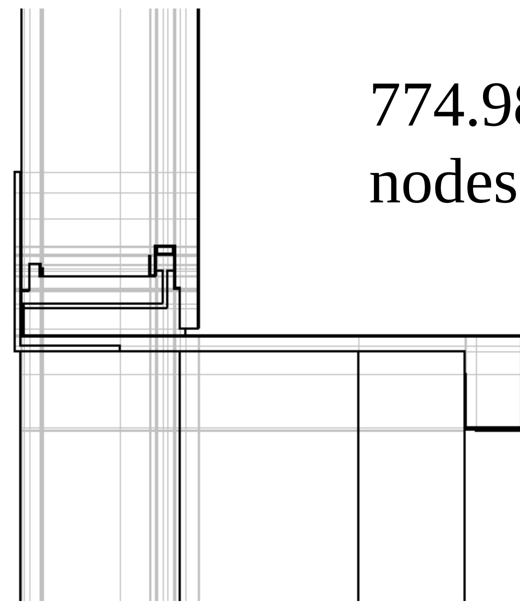


Numerical simulations – geometrical complexity

- ISO 10211: when λ > 3 W/mK, no simplification allowed
- Grid of 0.1mm required
- Non-orthogonal parts increase # nodes

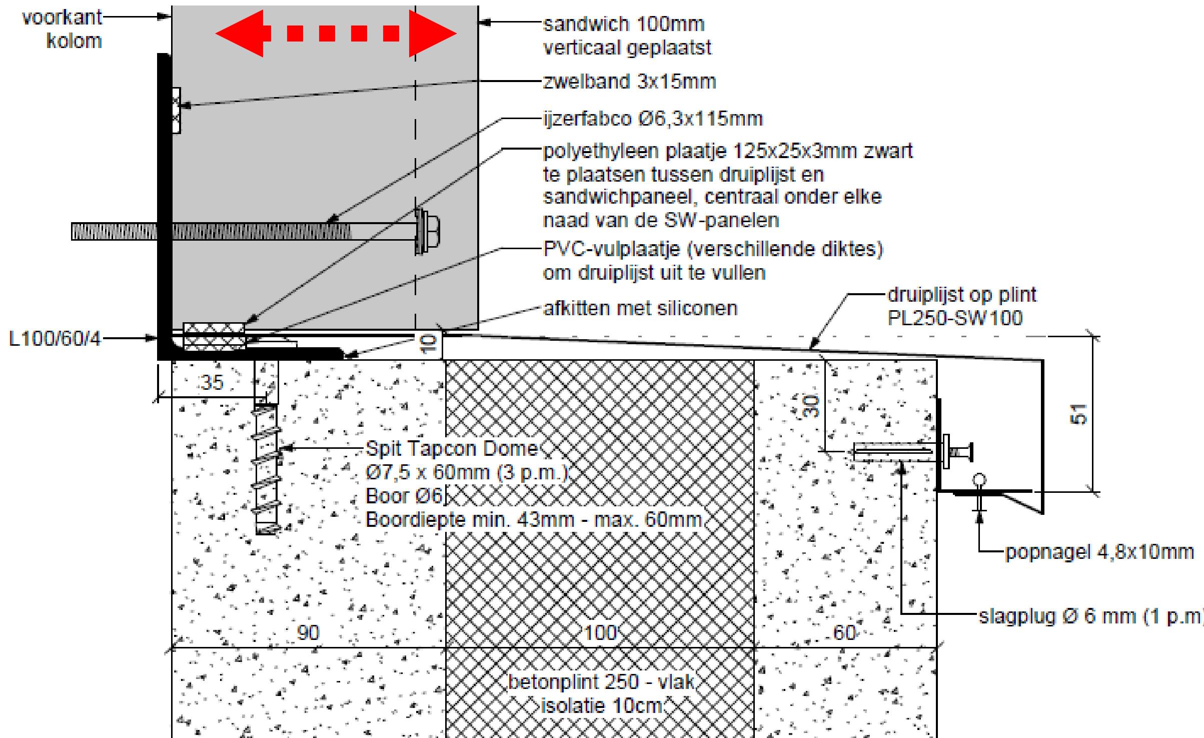


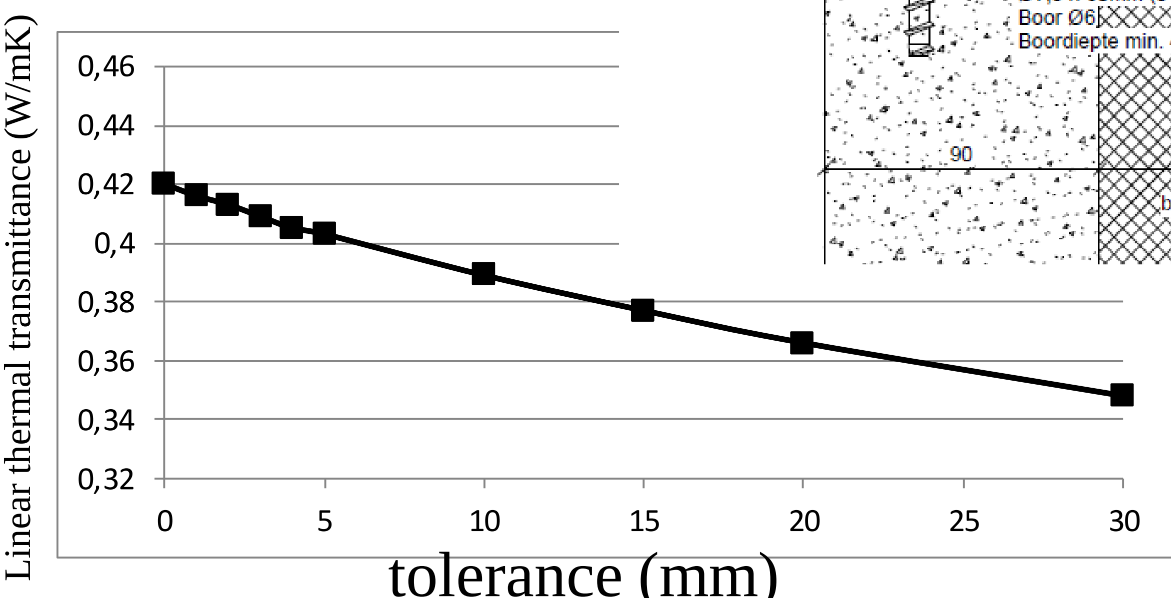
4.353.425
nodes



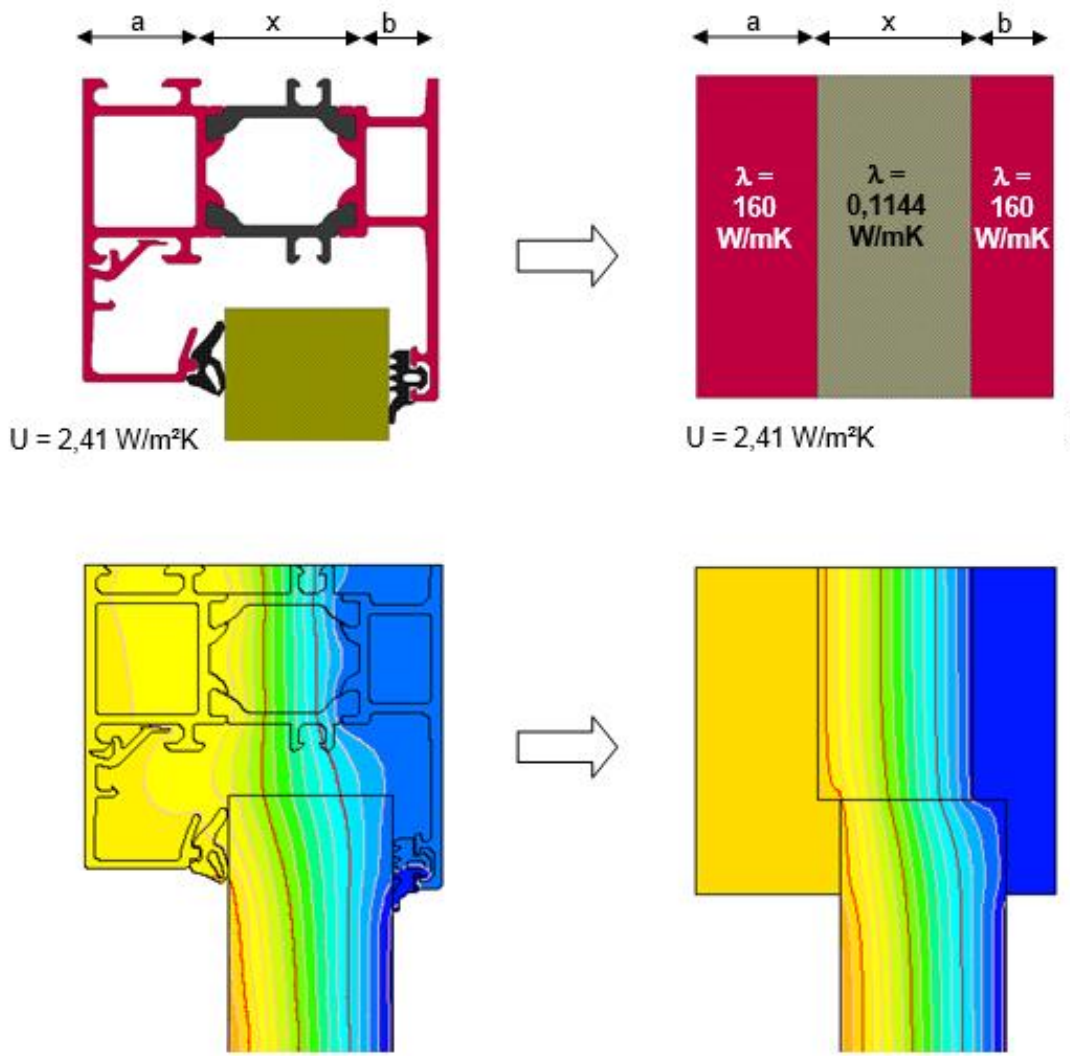
774.984
nodes

Numerical simulations – installation tolerance

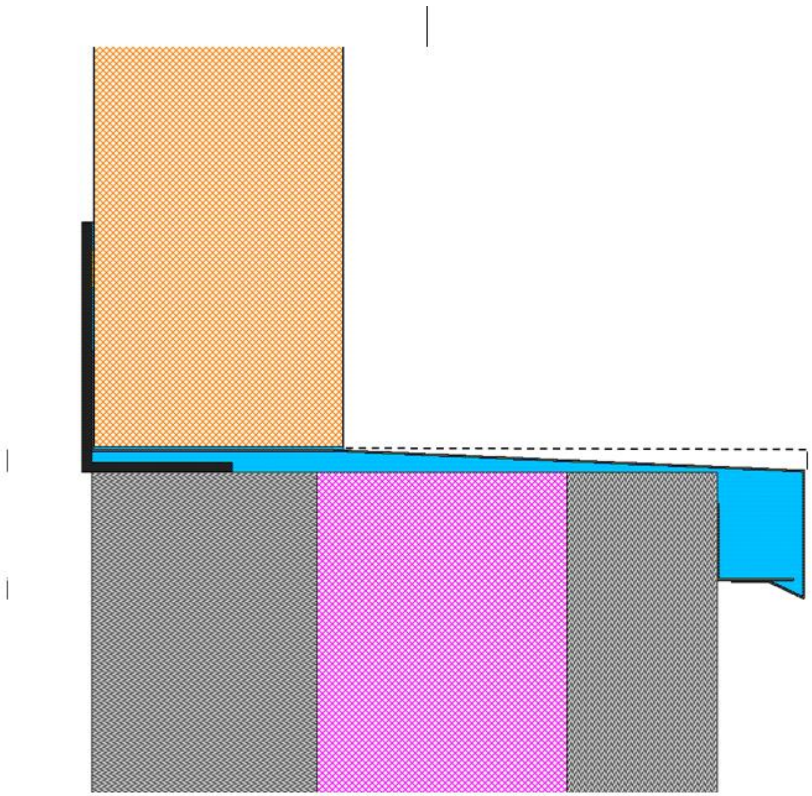


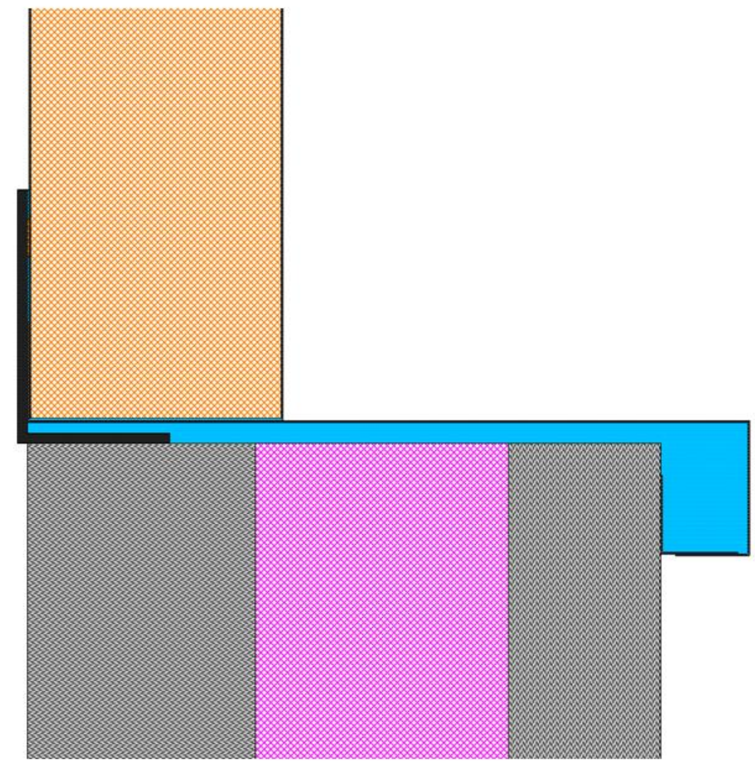


Numerical simulations – window frames



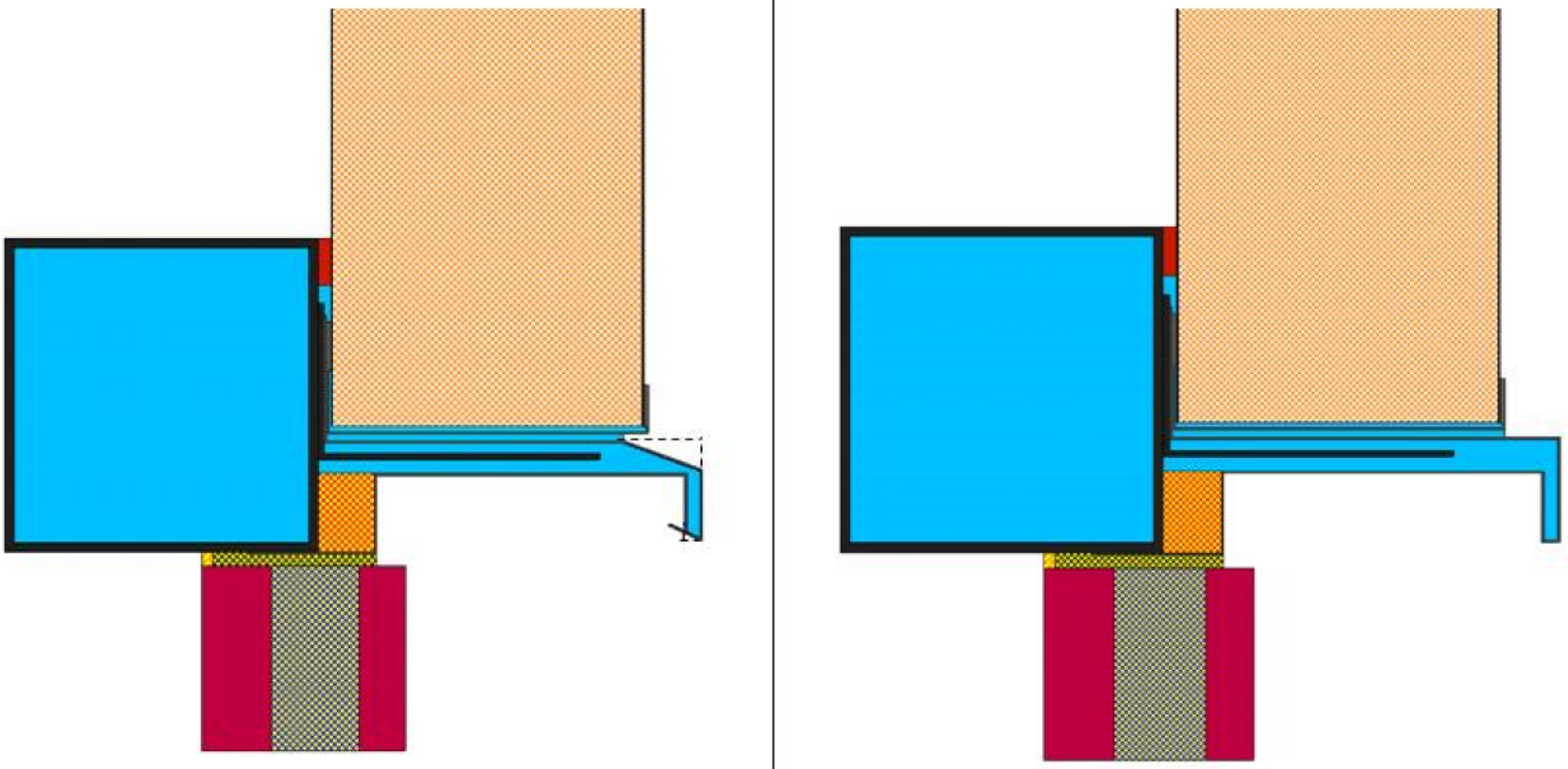
Numerical simulations – straightening things up





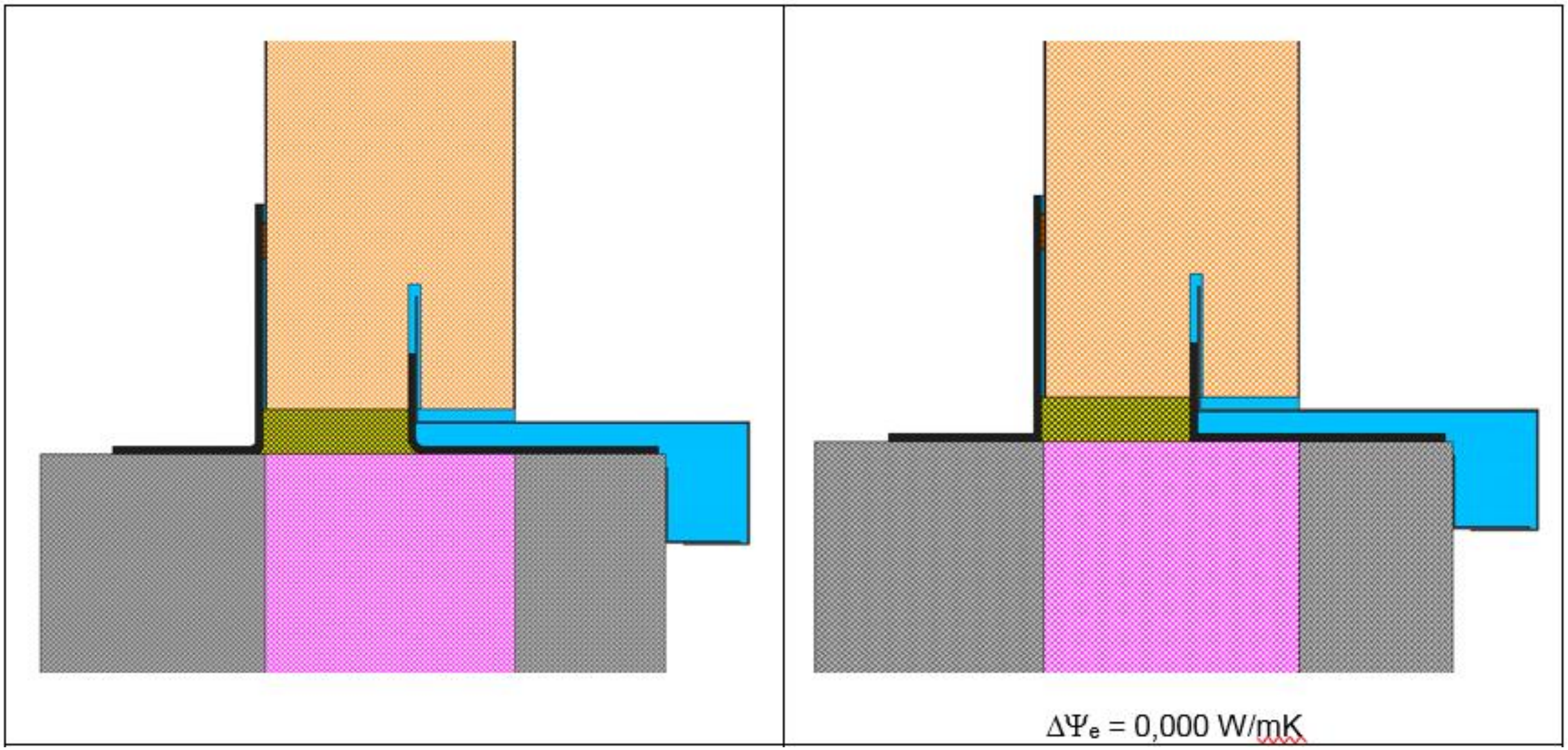
$\Delta\Psi_e = + 0{,}005$ W/mK

Numerical simulations – straightening things up

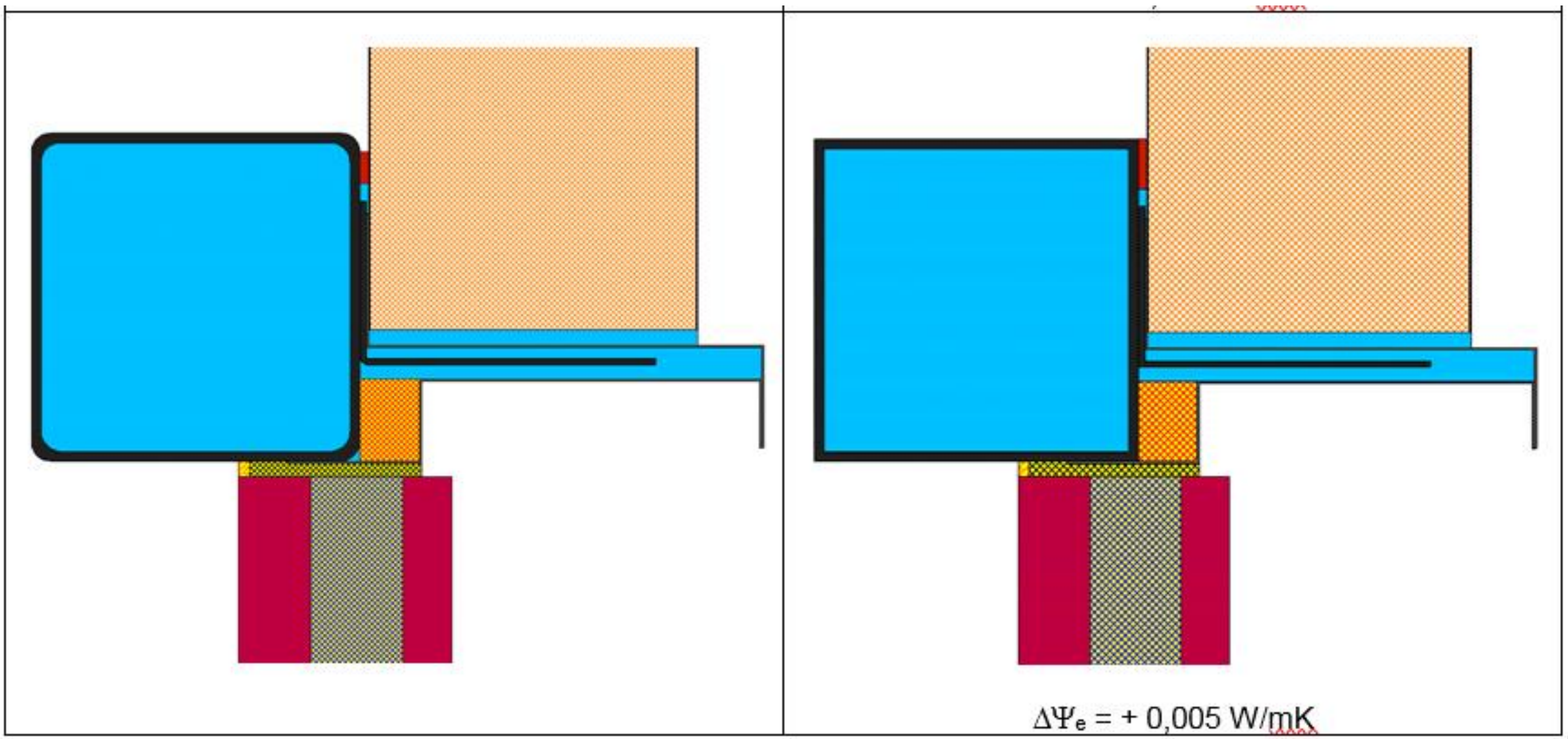


$\Delta\Psi_e$ = - 0,008 W/mK

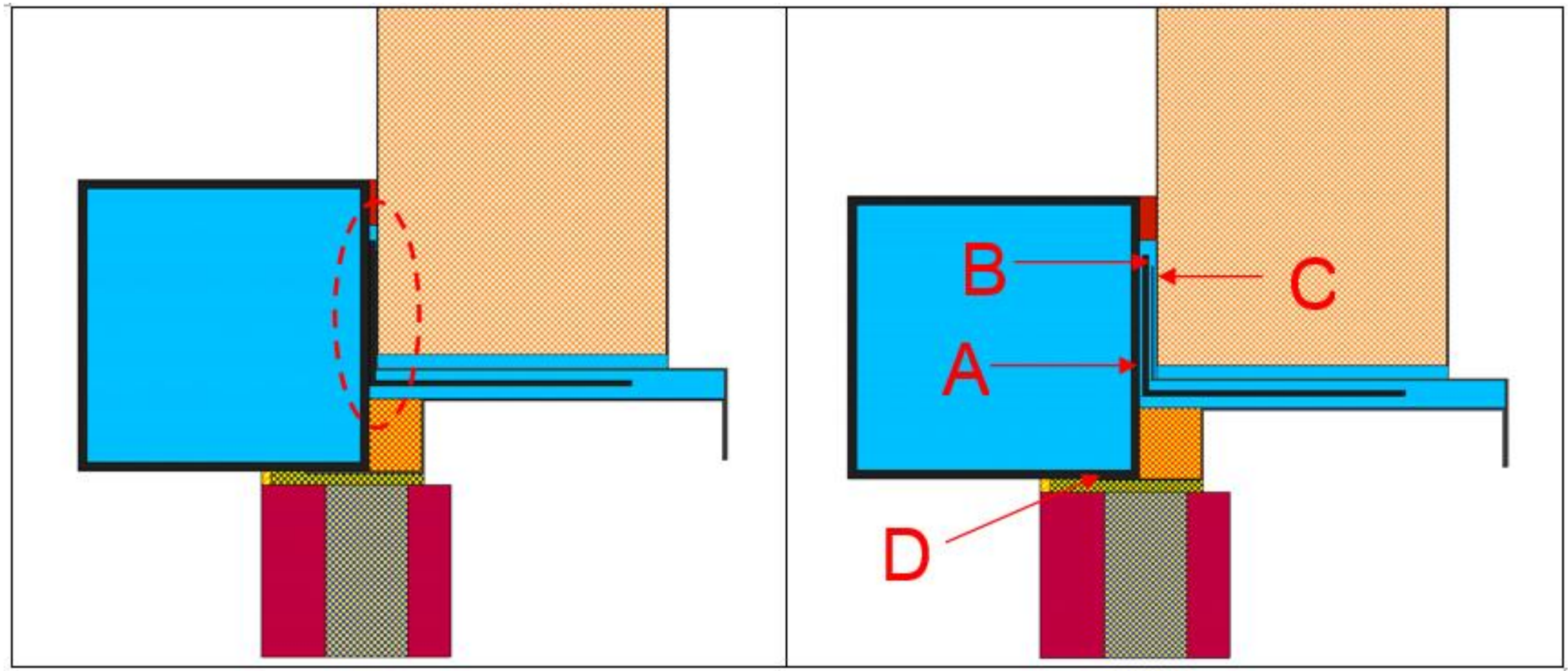
Numerical simulations – straightening things up



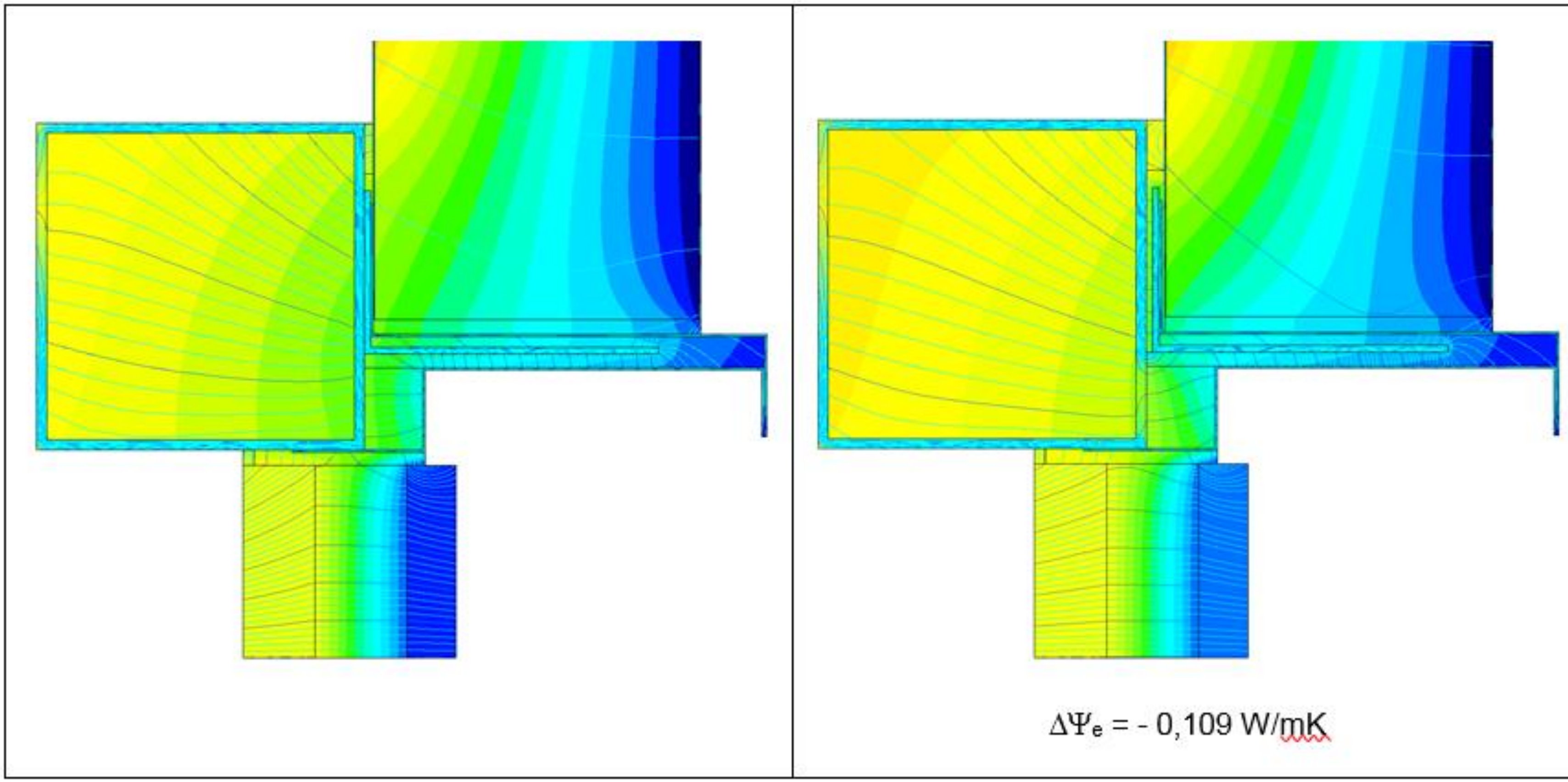
Numerical simulations – straightening things up



Numerical simulations – perfect contact?



Numerical simulations – perfect contact?



Thermal Bridges

Calculation, criteria, impact, and practical application

Prof. Nathan Van Den Bossche
Building Physics and Services, Ghent University, Belgium