# Current calculation rules for thermal bridges and resulting problems for the practical use

**Dr.-Ing. Kai Schild**

## Main topics and questions to be answered

- **Accuracy (→ Comparison of ISO 13370 and 3D-FE-calculations)**

  **→ How good do the results agree?**

- **Modeling (→ Model geometry and boundary conditions according to ISO 10211)**

  **→ What temperature should be used at the lower model border in the ground?**

  **→ Should a U-value according to ISO 13370 be used in ISO 10211?**

  **→ How should horizontal cross sections below ground be treated?**

  **→ How to generate models for ground coupled thermal bridges?**

- **Simplification (→ Complex geometries like frames or shutters)**

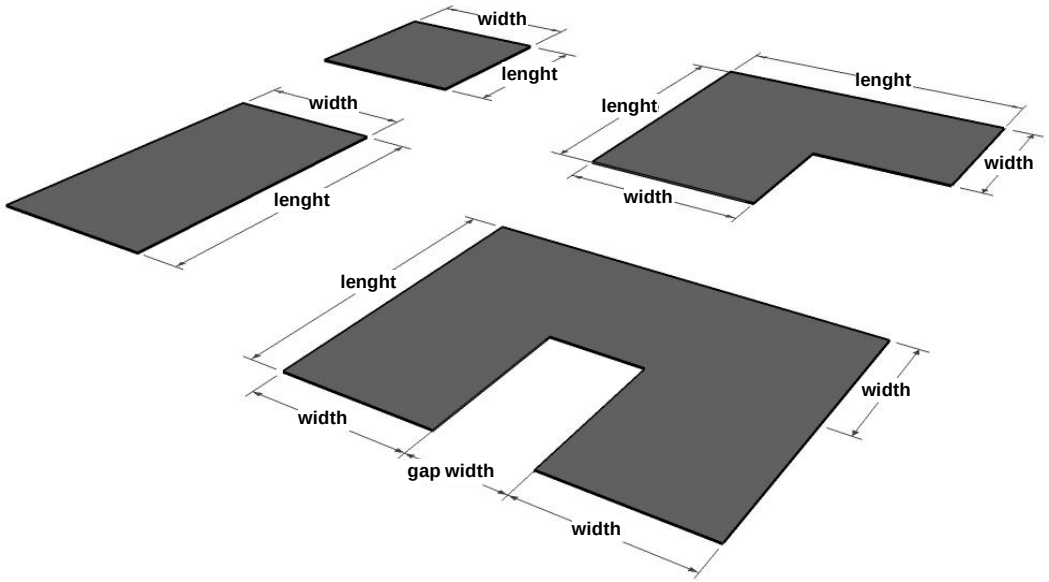
  **→ Is it allowed to simplify a complex geometry when using ISO 10211?**

  **→ How can ψ-values be derived from U-values according to ISO 10077?**

# Heat transfer via the ground

## 3D finite element models used to gain comparative values

- **slab on ground**
  - **uninsulated**
    → thermal resistance: $R_f$ = 0.15 m²K/W
  - **whole area insulated**
    → $R_f$ = 0.9 / 1.7 / 3.2 m²K/W
  - **horizontal edge insulation**
    → $R_f$ = 2.0 m²K/W, length: 5 m
  - **vertical edge insulation**
    → $R_f$ = 2.0 m²K/W, depth: 2 m
- **heated basement**
- **unheated basement**

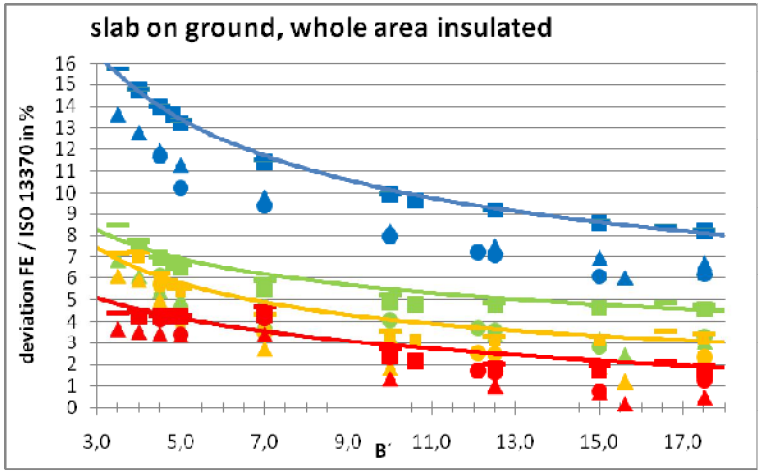


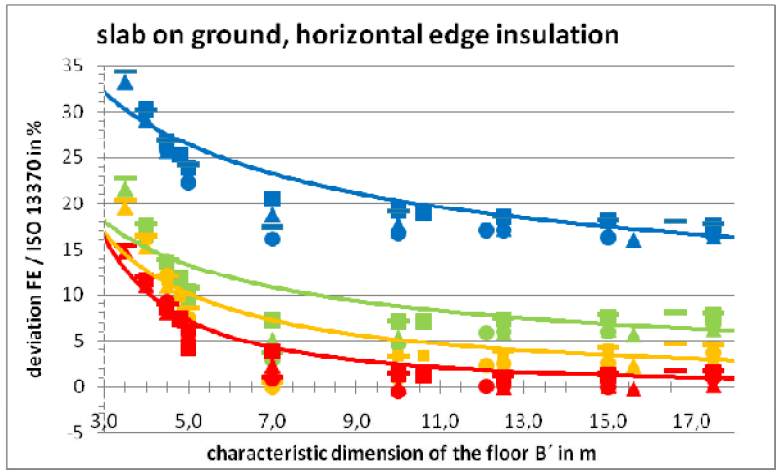

→ **different sizes**

→ **different geometries**

# Heat transfer via the ground

## Comparison (U-values) of ISO 13370 and 3D-FE-calculations (Example)




- **symbols represent different geometries**

  **line: rectangle, square: square, triangle: L-shape, circle: U-shape**

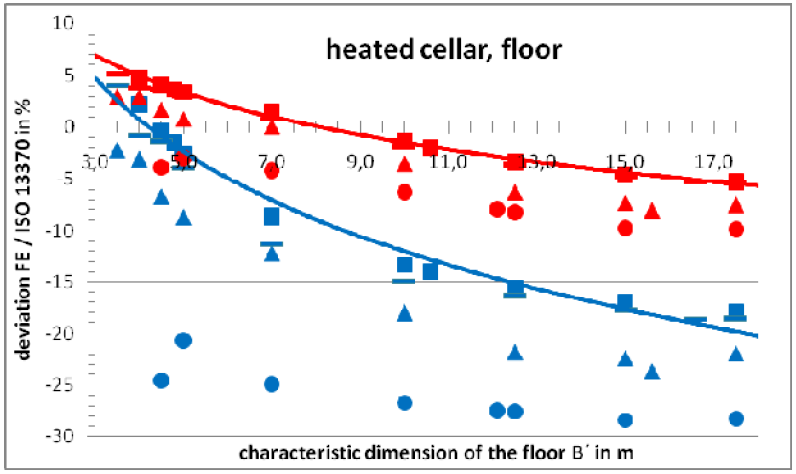
- **colors represent different insulation thicknesses**

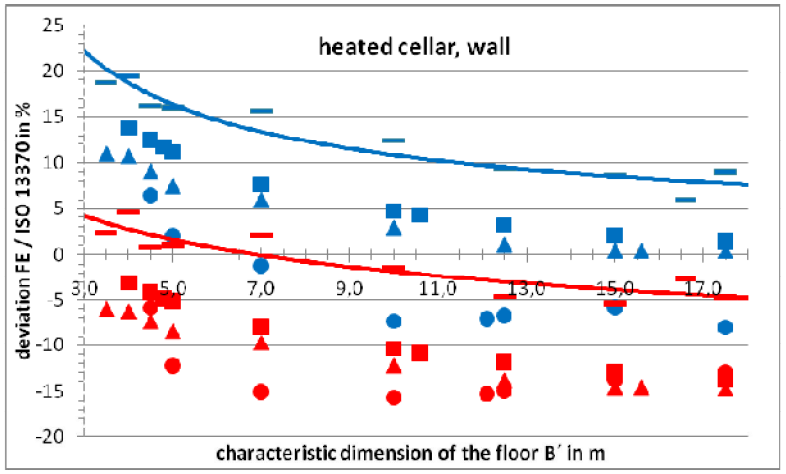
  **blue: uninsulated → red: well insulated**

**→ ISO 13370 underestimates the U value for small slabs und uninsulated slabs**

# Heat transfer via the ground

## Comparison (U-values) of ISO 13370 and 3D-FE-calculations (Example)




**cellar floor:**

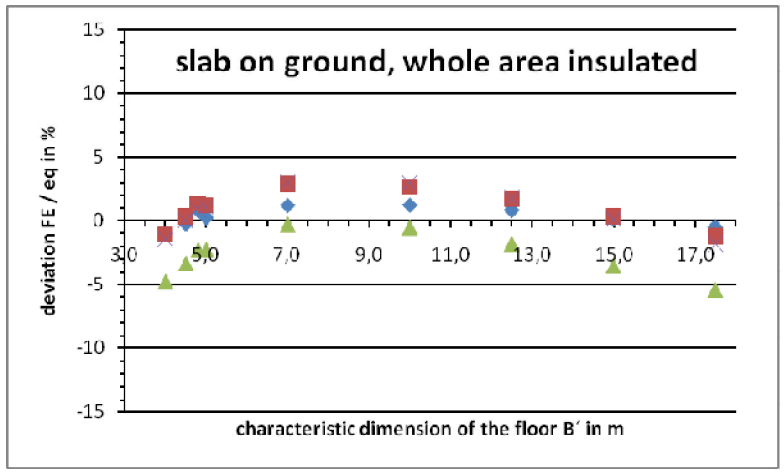
**→ ISO 13370 overestimates the U-value for most cases**

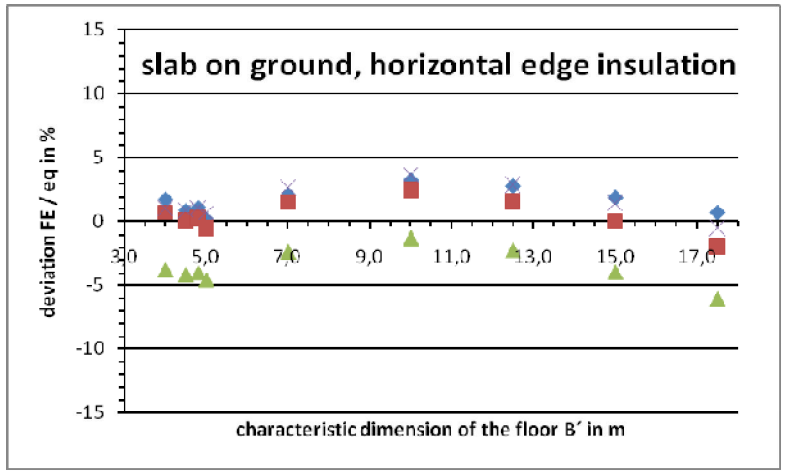
**cellar wall:**

**→ ISO 13370 underestimates the U-value for uninsulated walls**

# Heat transfer via the ground

## First guess for a new set of equations



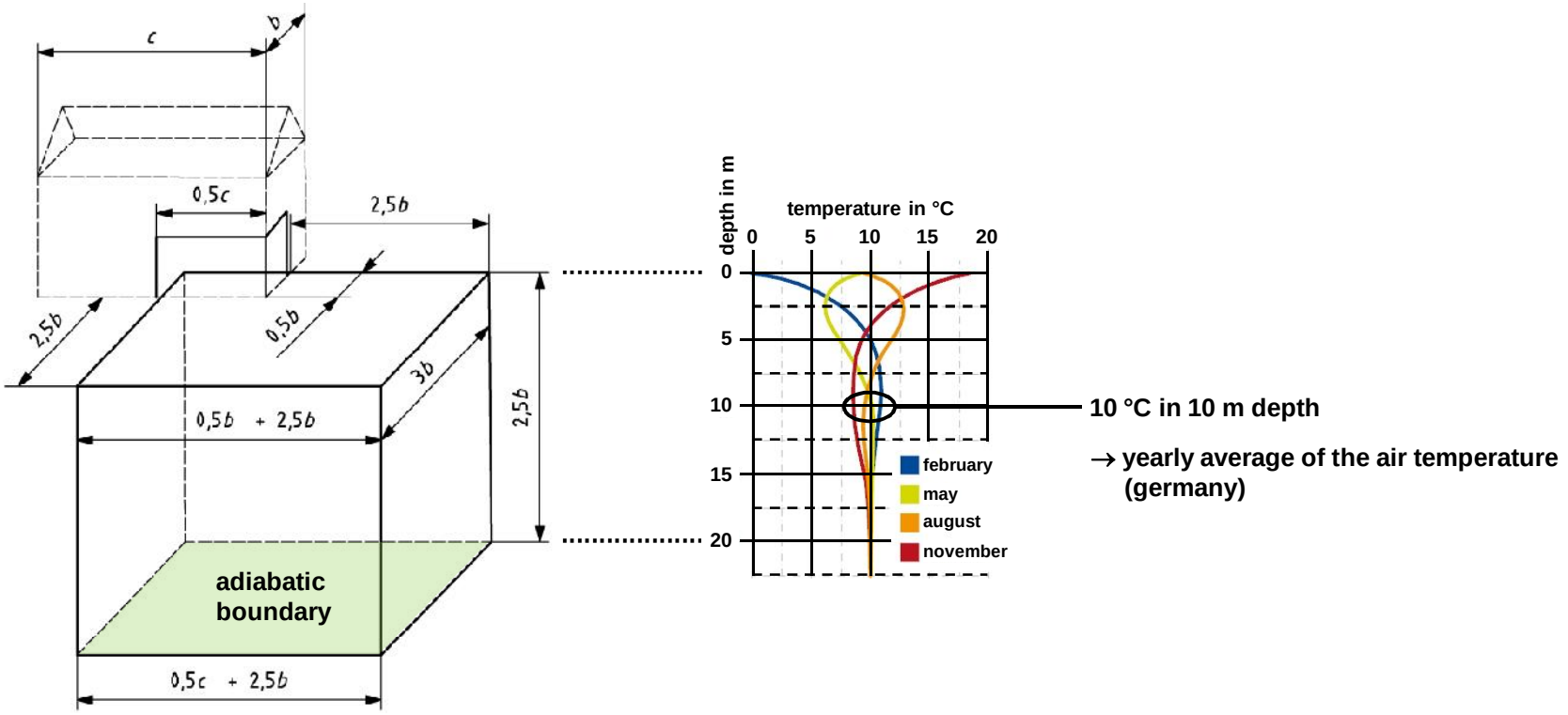




$$U_f = \begin{cases} \left(-1{,}46 \cdot \ln\left(\sqrt{R_f}\right) + 1{,}06\right) \cdot B'^{\,0{,}29 \cdot \sqrt{R_f} - 0{,}83} & R_f < 1 \\ \left(3.77 \cdot e^{-1{,}29 \cdot \sqrt{R_f}}\right) \cdot B'^{\,-0{,}96 \cdot e^{-0{,}59 \cdot \sqrt{R_f}}} & R_f > 1 \end{cases}$$

$$U_f = \begin{cases} \left(-0{,}36 \cdot \ln R_f + 0{,}64\right) \cdot B'^{\,-0{,}72 \cdot e^{-0{,}55 \cdot \sqrt{R_f}}} & R_f < 1 \\ \left(-0{,}31 \cdot \ln R_f + 0{,}64\right) \cdot B'^{\,-0{,}72 \cdot e^{-0{,}55 \cdot \sqrt{R_f}}} & R_f > 1 \end{cases}$$

# Heat transfer via the ground

## Boundary condition at the horizontal cut-off plane in the ground (regarding both ISO 13370 and ISO 10211)

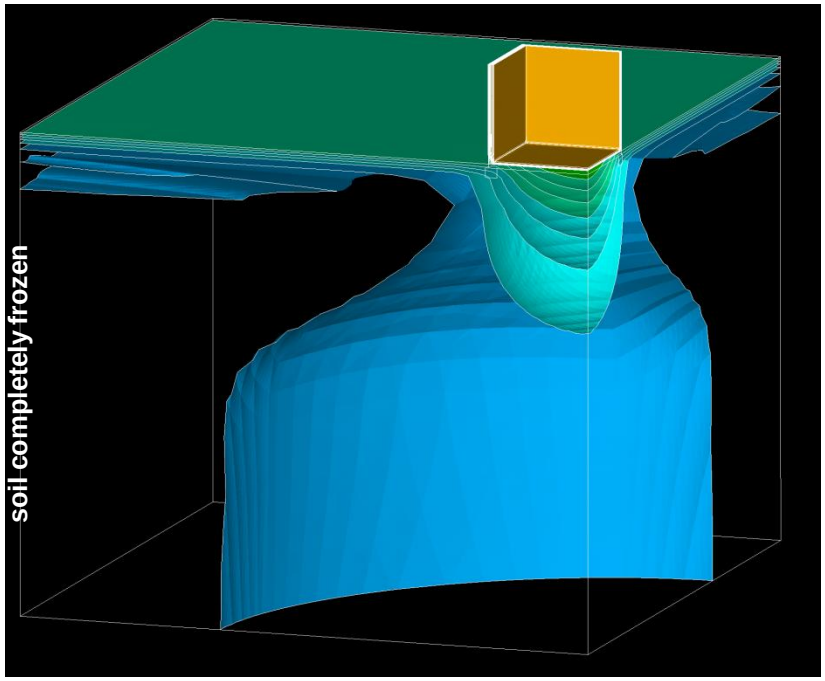



**ISO 10211 (and ISO 13370)** **more realistic**

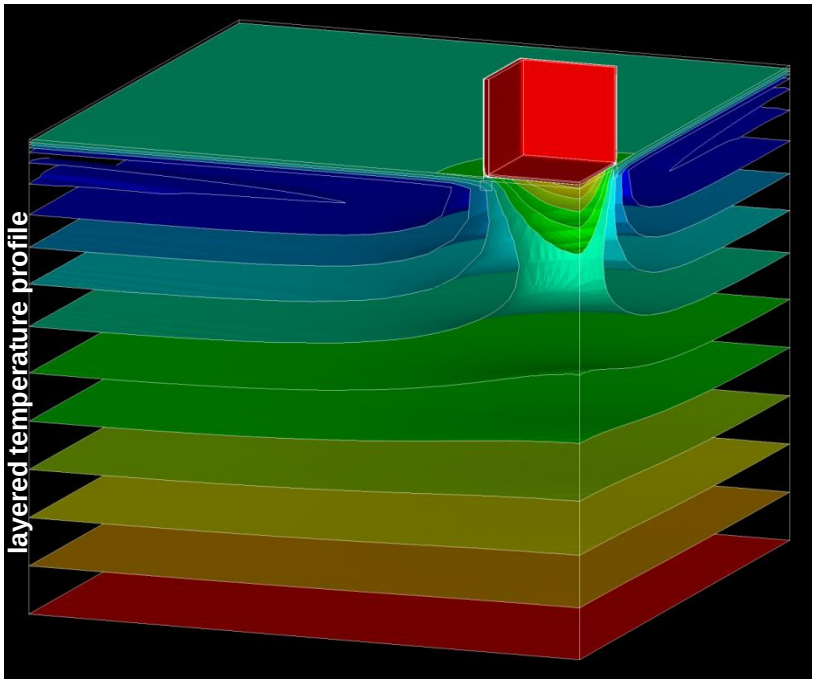
# Heat transfer via the ground

## Boundary condition at the horizontal cut-off plane in the ground

## Typical temperature distribution for both alternatives:




ISO 10211 (and ISO 13370)

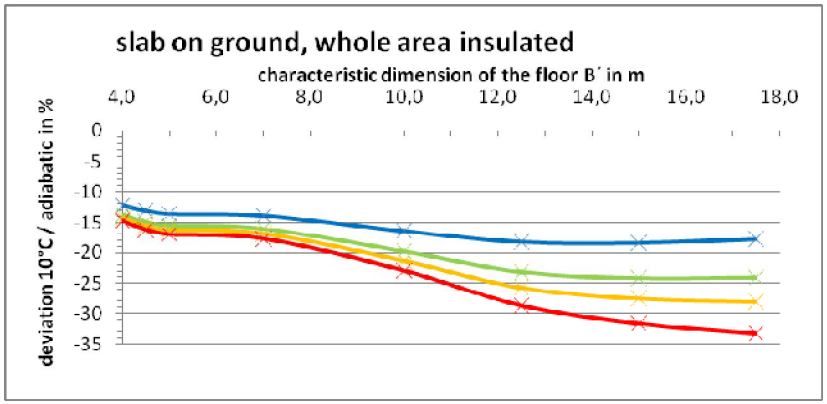


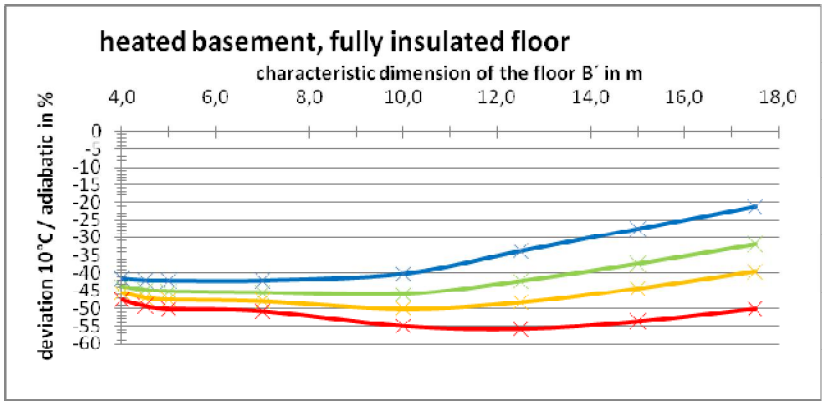

10°C in 10 m depth

# Heat transfer via the ground

## Boundary condition at the horizontal cut-off plane in the ground

## Comparison of the heat flows for two examples:



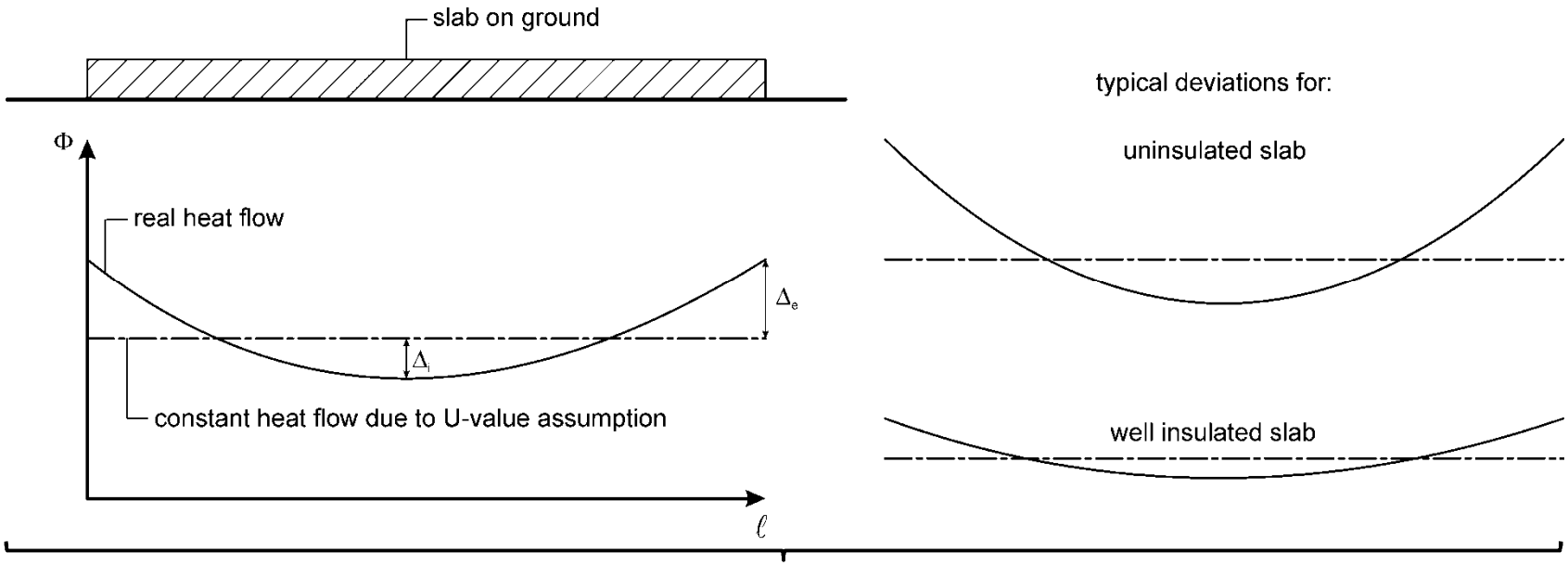

- **all 3D-FE-calculations use square shaped slabs**
- **colors represent different insulation thicknesses**

  **blue: uninsulated → red: well insulated**

**→ adiabatic boundary condition extremely overestimates the heat flow**

# Heat transfer via the ground

## Is a U-value according to ISO 13370 suitable to evaluate thermal bridges?



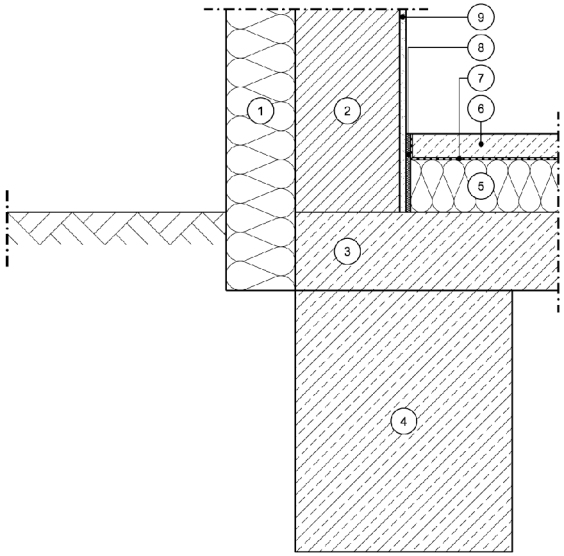

$$\psi = \frac{\Phi^{2D} - \Phi_0}{\Delta\theta} = \frac{\Phi^{2D} - \sum U \cdot \ell \cdot \Delta\theta}{\Delta\theta}$$

$\Delta_i \rightarrow$ heat loss estimated too high by U-value $\rightarrow$ influence of thermal bridge underestimated

$\Delta_e \rightarrow$ heat loss estimated too low by U-value $\rightarrow$ influence of thermal bridge overestimated

# Heat transfer via the ground

## Is a U-value according to ISO 13370 suitable to evaluate thermal bridges?



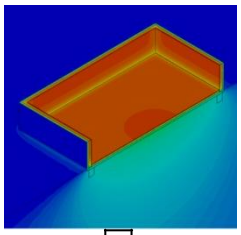

**Index:**
**1** thermal insulation, d = 16 cm, λ = 0.035 W/(mK)
**2** Brick masonry, d = 24 cm, λ = 0.99 W/(mK)
**3** concrete, d = 18 cm, λ = 2.3 W/(mK)
**4** strip foundation, b/d = 50/60 cm, λ = 2.0 W/(mK)
**5** thermal insulation, d = 12 cm, λ = 0.040 W/(mK)
**6** screed, d = 6 cm, λ = 1.4 W/(mK)
**7** vapour barrier
**8** flanking strip, d = 1 cm, λ = 0.040 W/(mK)

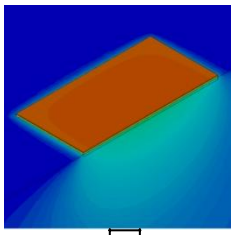
**Example: typical wall/floor junction**

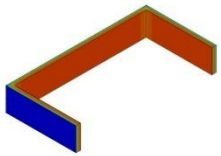
**1. ISO 13370 + ISO 10211**

$$\psi_{ISO10211} = \frac{\Phi^{2D}}{\Delta\theta} - (U_{wall} \cdot l_{wall} + U_{slab} \cdot l_{slab}) = 0.188 \frac{W}{mK}$$

**2. heat flow differences from 3D-FE-models**


1

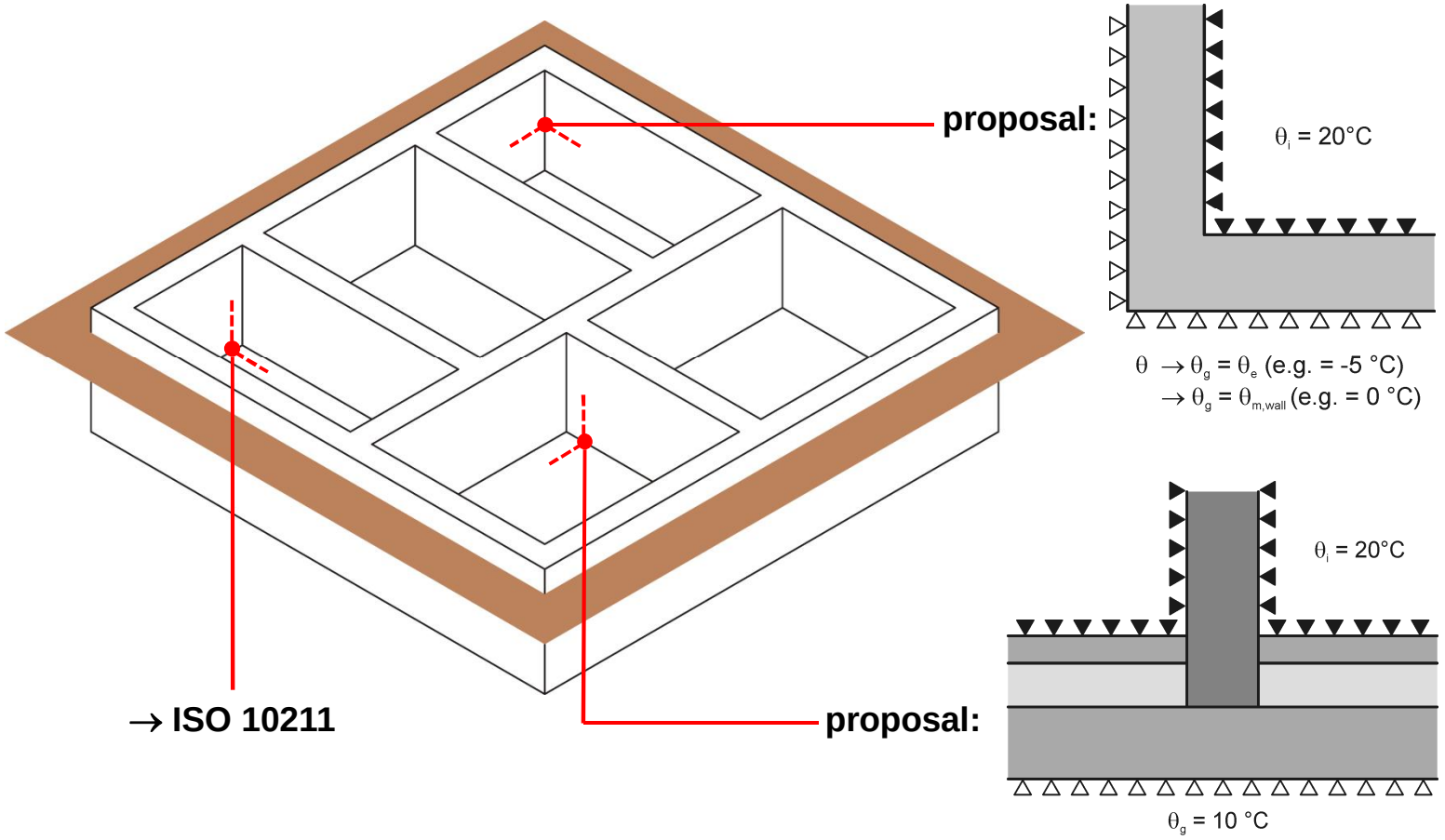

2


3

$$\psi_{3D-FE} = \boxed{1} - \boxed{2} - \boxed{3} = 0.31 \frac{W}{mK}$$

# Heat transfer via the ground

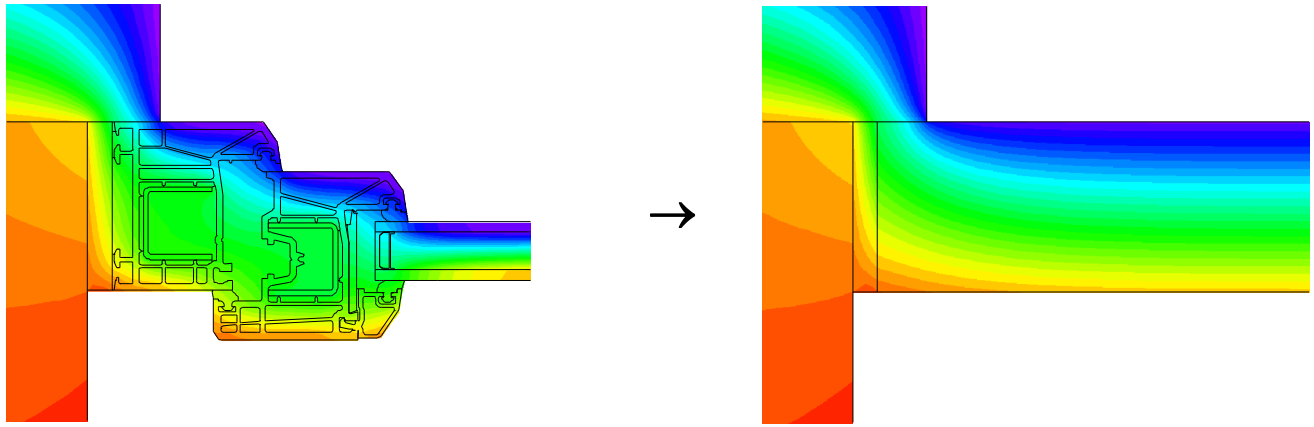
## Model geometry and boundary conditions for ground coupled details



# Detailed building components

## Simplification of complex geometries

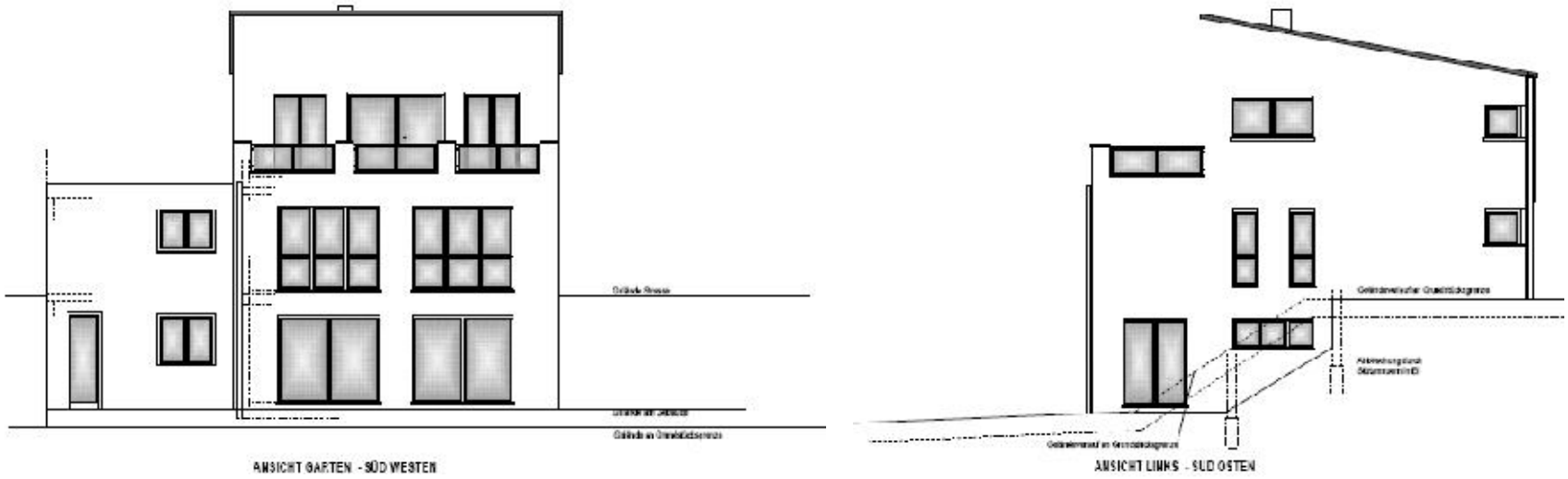
**Not allowed according to ISO 10211:**



**… but simplification is the only way for thermal bridge calculations in an early planning stage!**

# Detailed building components

## Deriving ψ-values from U-values according to ISO 10077




**Two alternatives:**

**1. ISO 10077 + ISO 10211 → 2 facades, 12 U-values, 36 thermal bridges, not feasible**

**2. average U-value + ISO 10211 → 3 thermal bridges, practical solution, not ISO-conform**

## Conclusions

- **ISO 13370 algorithms need some adjustment**
- **the boundary condition of the horizontal cut-off plane in ground should be changed to the yearly average of the air temperature**
- **a linear thermal transmittance does not describe the energetic quality of a ground coupled thermal bridge**
- **the modeling for horizontal cross sections below ground and thermal bridges below slabs has to be described in ISO 10211**
- **Simplification strategies for details with complex geometries are needed in ISO 10211**
- **Hints on how to treat individual window U-values with thermal bridges should be integrated in ISO 10211 or ISO 10077**