Digital Learning Paths

Field	***Central Heating***
Chapter	***Heating theory and heating techniques***
Subtitle	***Thermal bridge***

Thermal Bridges

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What is a thermal bridge?

Definition: A thermal bridge is defined as that part of the building envelope, in which its thermal resistance appears reduced compared to the thermal resistance of the rest of the shell.

In practice**, thermal bridges** appear in the thermal envelope of the building as thermally weak points or as discontinuities in the shell. At these points there is a greater flow of heat, compared to the rest of the building shell, which must be calculated, on the one hand, to be taken into account in the energy study of the building, and on the other hand, to avoid possible moisture and the appearance of mold.

There are two types of thermal bridges:

Constructional: They are due to a break in the continuity of the thermal insulation layer and its intensity depends on the created jump of the discontinuity.

Geometric: They are due to the geometry of the building, without breaking the continuity of the thermal insulation layer and its intensity depends on the difference in size of the external and internal surfaces.

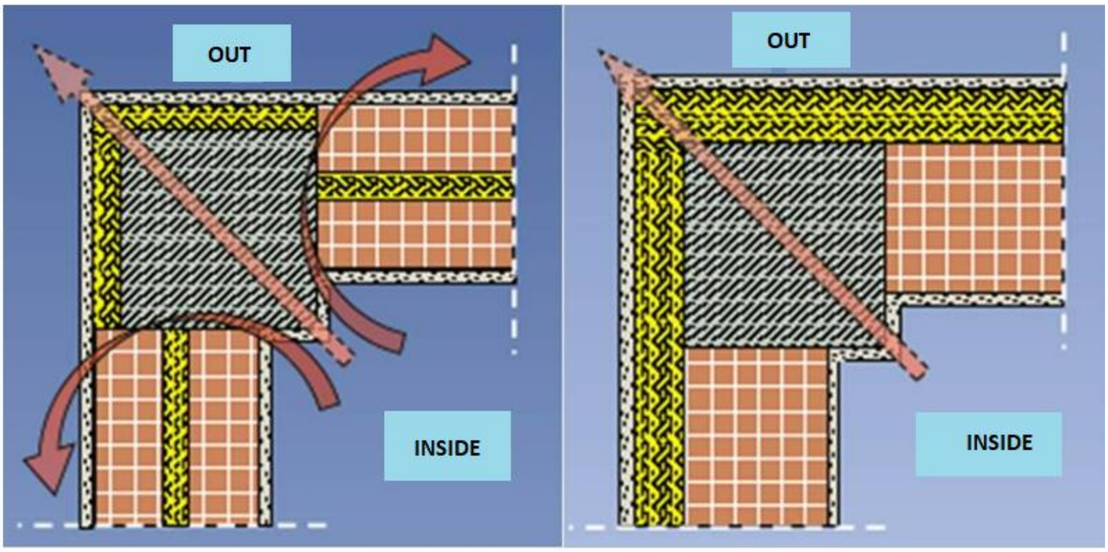

Figure 1: On the left we see a structural thermal bridge and on the right a geometric one

(Energy and Buildings, Experimental analysis of seasonal temperature characteristics and cooling and heating energy consumption of a slim double-skin window.)

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Thermal bridges are weak points of building envelopes that can lead to **energy losses, collection of moisture, and formation of mold** in the building fabric. To detect thermal bridges of large building stocks, drones with thermographic cameras can be used.

The emissions of carbon dioxide CO_2 from the operation of buildings have increased to their highest level yet to around of total global energy-related emissions. Thermal energy is particularly pertinent as more than half of global household energy use is for space and water heating. A common reason for heat losses of buildings are thermal bridges. Thermal bridges are areas of the building envelope with low thermal resistance that conduct heat faster from the warmer inside to the colder outside than adjacent areas. Reasons for this are the geometry of constructions, different thermal conductivities of used materials, or air leaks of the building envelope. Energy losses caused by thermal bridges can make up to one third of the transmission heat loss of an entire building. Moreover, they may lead to dampness and mould growth, which in the long term degrades the building fabric and is associated with health concerns caused by poor indoor air quality. For buildings inhabitants, thermal bridges also can lead to uncomfortable spaces due to cold interior surfaces.

Calculation of thermal bridges

During their calculation, thermal bridges are divided into point and linear, in two and three dimensions.

The linear Ψ-value is calculated using the external dimensions using the formula:

$$\Psi = \frac{Q_{2Dim} - Q_{1Dim}}{\ell \cdot \Delta\vartheta}$$

Where,

Q1Dim = S Ai· Ui · DJi
Q 2Dim: Heat flow, calculated using a numerical method

Δθ: Temperature difference between indoor and outdoor environment

l: Thermal bridge length

and

Ui: U-values of the structural elements of the building

Ai: Structural element of the building with area number “i”, (using external dimension reference)

Δθi: Temperature difference between internal and external surfaces of structural element “i”

The point Ψ-value is calculated in the same way, without the length l in the denominator.

What is the Ψ coefficient?

The coefficient Ψ functions as a correction in the calculations of the heat flows made assuming a one-dimensional flow at the locations of the thermal bridges. It can take positive, negative, or even zero values. A positive value of Ψ indicates that the two-dimensional heat flow is greater than that which would be obtained by calculating for one-dimensional flow. On the contrary, the negative value of Ψ indicates that there is an overestimation of the heat flow when it is considered as one-dimensional, i.e. the value of the flow is smaller than that found with one-dimensional calculations. Finally, a zero value of Ψ indicates that there is no heat flow.

Example: Projecting balcony slab

The concrete slab of the floor slab continues up to the balcony thus interrupting the insulation of the external masonry shell. In existing buildings in places like this there is an increased risk of moisture, and it is recommended to cover the entire cantilever with insulation. Many times, however, this is not possible, and we resort to solutions that require a heat flow study. Through two-dimensional heat flow calculation programs we check the heat flow and the case of moisture occurrence.

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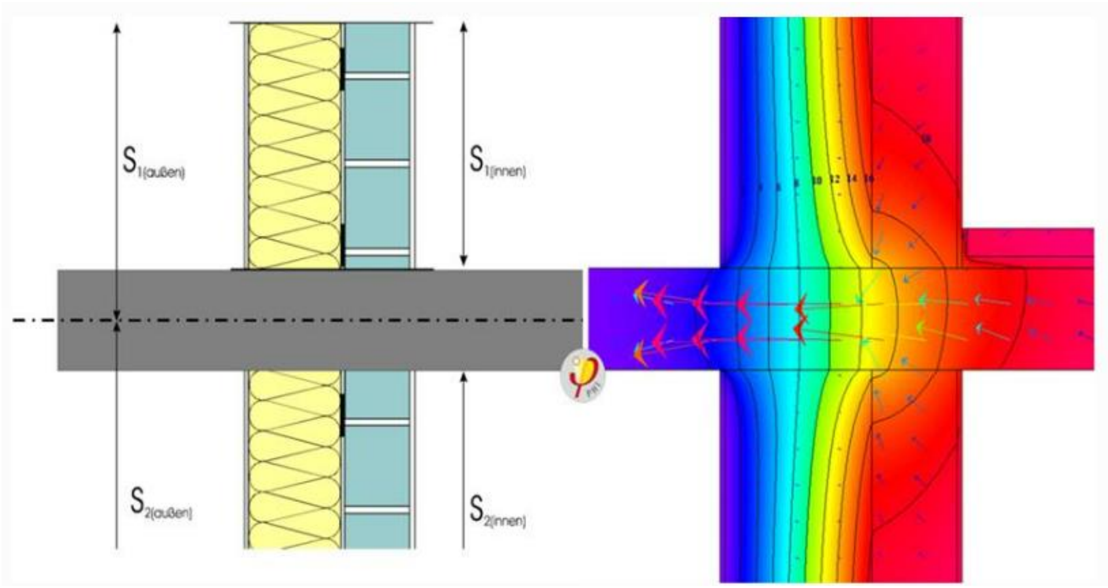

Figure 2: Thermal analysis of a structural element, which interrupts the building shell

The computational solution and treatment of thermal bridges in buildings requires specialized knowledge and experience and can affect up to 25% of the building's energy requirement for heating or cooling. It is extremely important to resolve the thermal bridges of window frames, in order to achieve the optimal behavior of the window frame, which means a positive energy balance.

Thermal insulation - Thermal bridges

The humidity problem arises as the water vapor of the indoor air meets cold surfaces (due to insufficient thermal insulation) and liquefies when the surface temperature is below the point air dew. The consequence of this phenomenon is to create suitable conditions for the growth of fungi (mold). The problem worsens when there is no good ventilation and renewal of the indoor air, or in places where the air has a high water vapor content for (ex. bathrooms).

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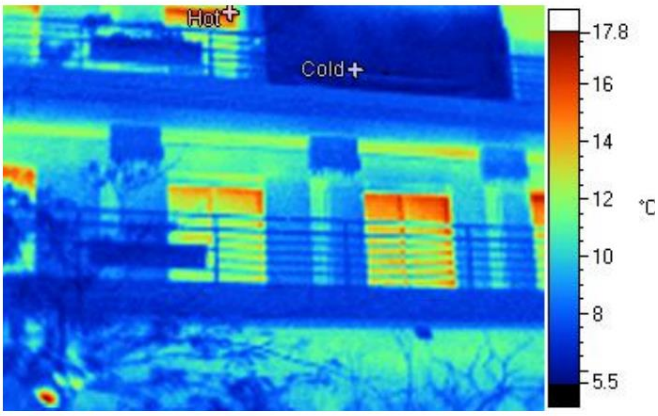

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Calculation of Thermal Bridges

The vertical thermal bridges are in the floor plans of the building, given that their main dimension is developed in height, their length is measured based on drawings of the sections.

Three subcategories are distinguished:

– external corner thermal bridges (EXG)

– internal corner thermal bridges (ESG)

– thermal bridges joining structural elements (EDS).

Principles of calculation of the coefficient of thermal conductivity Um

Calculation of the average coefficient of thermal permeability of the entire building Um:

$$U_m = \frac{\sum_{j=1}^{n} A_j \cdot U_j \cdot b + \sum_{i=1}^{\nu} l_i \cdot \Psi_i \cdot b}{\sum_{j=1}^{n} A_j} \qquad [W/(m^2 \cdot K)]$$

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Um [W/(m²·K)]: the average thermal permeability coefficient of the building envelope

n [–] : the number of individual structural elements in the building shell

v [–] : the number of thermal bridges that develop at the boundaries of the shell

Aj [m²] : the surface area occupied by each structural element

Uj [W/(m²·K)] : the coefficient of thermal permeability of each structural element j

lj [m] : the total length of each type of thermal bridge developed in building envelope

Ψj [W/(m·K)] : the coefficient of linear thermal permeability of each type

thermal bridge,

The reduction factor (b):

•On surfaces that are in contact with the outside air.

The coefficient takes a value of b = 1.0, since the quantity A·U is considered the real one

calculated. The value b = 1.0 applies to both vertical surfaces and

horizontal, whether the heat flow in the latter is from top to bottom or from bottom to top.

The reduction factor (b):

•On surfaces that meet a neighboring building.

Although in the case of a neighboring building the transferred amount of heat

through a structural element touching a corresponding neighboring structural element

is reduced compared to the amount of heat transferred through a

of a structural element that meets the outside air, or transported

amount of heat should remain overestimated with coefficient value

b =1.0,

because the lifetime of the neighboring building is undetermined.

It will be the same

treatment whether the areas of the neighboring building are heated or not.

On the contrary, the energy inspection assesses its actual condition building and

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the actual amount of energy transferred through the structures is evaluated

elements coming into contact, post-structural elements of the building, principles of calculation of the coefficient of thermal permeability Um

The reduction factor (b):

•On a horizontal roof under a non-insulated roof.

The reduction factor maintains the value b = 1.0, as the deviation correction

has already been done when calculating the coefficient of thermal conductivity U of the cross-section, considering the resistance of the air layer between the horizontal ceiling

and the pitched roof.

•On a surface in contact with the ground.

For surfaces in contact with ground it is considered that the correction of

heat fluxes using the equivalent coefficient of thermal conductivity is sufficient

and therefore no further correction is required. Therefore in this case

b=1.0 is taken.

Principles of calculation of the coefficient of thermal conductivity Um

The reduction factor (b):

On a surface that meets a closed, unheated space.

In this case the heat flow through the structural element that separates the

heated from the unheated space is equal to the heat flow from the unheated

heated space to the external environment, affected by quantity heat transferred or absorbed through ventilation in the unheated space.

The reduction factor b is calculated either analytically from the relevant formula, or

the feature is provided in all cases that the structural element meets unheated space to be taken as a simplifying assumption as a value of the reducing factor b = 0.50.

The reduction factor (b):

$$b_u = \frac{\sum(U_{ua} \cdot A_{ua}) + (n_u \cdot V_u \cdot c_{air})}{\sum(U_{ua} \cdot A_{ua}) + \sum(U_{iu} \cdot A_{iu})} \qquad [-]$$

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Uuα [W/(m²·K)] : the coefficient of thermal permeability of a structural element that separates the non heated space from the external environment

Uiu [W/(m²·K)] : the coefficient of thermal permeability of a structural element that separates the heated space from the unheated space

Auα [m²] : the surface area of a structural element that separates the unheated space from the external environment

Aju [m²] : the surface area of a building element that separates the heated space from the unheated heated space

nu [h-1] : the number of air changes per hour

Vu [m3] : the volume of the unheated space

c_{air}[J/(m3·K)] : the heat capacity of air per unit volume: air = 0.33 W/(m3·K).

Exercises

1st

Calculate the minimum thickness of insulating material that must be placed on external masonry (climate zone D) of a house being radically renovated, consisting of 2 cm thick coating inside and out and 18 cm thick optical bricks.

Data: λins=0.035 W/mK, min= 0.870 W/mK, min=0.450 W/mK

Solution

According to table 3.4a of TOTEE 2017, the thermal permeability coefficient of the vertical structural element should be U≤0.40 W/m^2 K

The formula for calculating the thermal conductivity coefficient is

$$U = \frac{1}{Ri + \sum_{i=1}^{n} \frac{di}{\lambda \iota} + R\delta + Ra}$$

From table 2b of TOTEE 2 we find that

Ri=0.13 m2K/W

Ra=0.04 m2K/W

Rδ=0 because there is no air gap in the masonry.

Therefore,

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$$U = \frac{1}{Ri + \sum_{i=1}^{n} \frac{di}{\lambda\iota} + R\delta + Ra} \leq 0{,}40 \rightarrow$$

$$\frac{1}{0{,}13 + \frac{0{,}02}{0{,}870} + \frac{0{,}18}{0{,}450} + \frac{0{,}02}{0{,}870} + \frac{d\mu}{0{,}035} + 0 + 0{,}04} \leq 0{,}40 \rightarrow$$

$$\frac{1}{0{,}616 + \frac{d\mu}{0{,}035}} \leq 0{,}40 \rightarrow 1 \leq 0{,}2464 + 11{,}428 d\mu \rightarrow 0{,}7536 \leq 11{,}428 d\mu$$

$$d\mu \geq 0{,}0659\ m$$

The thickness of the insulation must be at least 7 cm.

It is emphasized that if it is a new building, the value of U results from table 3.3a and will be U≤0.35 W/m^2 K.

2nd

Calculate the minimum thickness of insulating material that must be placed on external masonry (climate zone B) of a house being radically renovated, consisting of a 2 cm thick coating inside and outside two optical bricks 9 cm thick each and an air gap without a 15 mm thick reflective surface.

Data: λins=0.035 W/mK, min= 0.870 W/mK, min=0.450 W/mK

SOLUTION

According to table 3.3.a of TOTEE 2017, the thermal permeability coefficient of the vertical structural element should be U≤0.50 W/m^2

$$U = \frac{1}{Ri + \sum_{i=1}^{n} \frac{di}{\lambda\iota} + R\delta + Ra}$$

From table 2b of TOTEE 2 we find that

Ri=0.13 m2K/W

Ra=0.04 m2K/W

And from table 3a of TOTEE 2 Rδ=0.17 for horizontal flow.

Therefore

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$$U = \frac{1}{Ri + \sum_{i=1}^{n} \frac{di}{\lambda\iota} + R\delta + Ra} \leq 0,50 \rightarrow$$

$$\frac{1}{0,13 + \frac{0,02}{0,870} + \frac{0,09}{0,450} + 0,17 + \frac{0,09}{0,450} + \frac{0,02}{0,870} + \frac{d\mu}{0,035} + 0,04} \leq 0,50 \rightarrow$$

$$\frac{1}{0,786 + \frac{d\mu}{0,035}} \leq 0,50 \rightarrow 1 \leq 0,393 + 14,285 d\mu \rightarrow 0,607 \leq 14,285 d\mu$$

$$d\mu \geq 0,0424\ m$$

The thickness of the insulation must be at least 5 cm.

It is emphasized that if it is a new building, the value of U results from table 3.3a and will be U≤0.45 W/m2 K

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References

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TOTEE 20701−2/2010 "Thermophysical properties of building materials and control of the thermal insulation adequacy of buildings".

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