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IMPROVEMENT OF CESTEC-ANCE THERMAL BRIDGES ABACUS

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ESTRATTO

Come è ben noto, l'edilizia comporta il 40% del consumo globale di energia ed è il settore con le più ampie possibilità di miglioramento. Per questo motivo le direttive europee 2002/91/CE e 2010/31/UE forniscono regole generali sull'efficienza energetica in edilizia. Dall'entrata in vigore di queste norme, gli edifici sono divenuti sempre più efficienti e quindi il ponte termico ha assunto sempre più influenza all'interno del bilancio energetico dell'edificio.

Lo scopo di questa tesi è quello di completare e validare l'abaco dei ponti termici redatto dal Dipartimento di Energia del Politecnico di Milano in collaborazione con ANCE[1] e con CESTEC[2]. Questo abaco è composto da schede che riportano, per ogni schematizzazione di ponte termico, le correlazioni (per le dimensioni interne ed esterne) che identificano la trasmittanza lineica in funzione di diversi parametri che rappresentano le caratteristiche termofisiche e geometriche degli elementi costruttivi in esame.

In primo luogo, per completare l'abaco, sono state sviluppate nuove correlazioni che esprimono il fattore di temperatura superficiale, fattore che permette di valutare la condensazione superficiale.

In secondo luogo si è deciso di validare parte delle correlazioni dell'abaco per capire quanto queste possano essere applicate alla realtà. A questo scopo sono state svolte delle simulazioni su nodi costruttivi reali e si è valutato l'errore che i risultati di queste generano in riferimento alla correlazione di riferimento.

Questa tesi quindi ha permesso di ottenere delle correlazioni che permettono di valutare anche la seconda conseguenza del ponte termico (la condensazione) e di stimare quale errore ci si possa aspettare nello studio di casi reali.

Le correlazioni determinate per il fattore di temperatura superficiale presentano un intervallo di confidenza spesso vicino a 0.01, valore che indica un buona relazione tra le variabili in esame. Dalla validazione emerge che l'impiego di stratigrafie non omogenee spesso può portare a valori al di fuori dell'intervallo di confidenza prescritto. Nei casi con un errore rilevante è necessario svolgere un'analisi più approfondita tramite ulteriori simulazioni bidimensionali.

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[1] ANCE: Associazione Nazionale Costruttori Edili.
[2] CESTEC: Centro per lo Sviluppo Tecnologico, l'Energia e la Competitività.

ABSTRACT

As well known, building determines 40% of the total energy consumption in the world and it is the sector which has the widest possibilities of improvement. It is for this reason that the European directives 2002/91/CE and 2010/31/UE provide general rules about the energy efficiency in buildings. Since these norms were established, buildings have become more and more efficient and so thermal bridges have more and more influence inside the building energy balance.

The general purpose of this thesis is to complete and validate the thermal bridges abacus drawn up by the Energy Department of *Politecnico di Milano* in collaboration with ANCE and CESTEC. This abacus is composed of reports which contain, for each thermal bridge schematization, the correlations (based on internal and external dimensions) which provide the linear thermal transmittance as a function of different parameters. These represent the thermophysical and geometrical characteristics of the building elements taken into consideration.

First, to complete the CESTEC abacus it has been necessary to develop new correlations about the temperature factor at the internal surface, the factor that allows the evaluation of the superficial condensation.

Secondly, it has been decided to validate part of the abacus correlations to understand how much these could be applied on real building junctions. For this purpose it has been evaluated the error generated by these real cases related to the correlation taken in exam.

Therefore this thesis has given the possibility to obtain some correlations which allow to estimate also the second effect of the thermal bridge (the condensation) and to evaluate the error which could be expected in real case studies.

The correlations for the temperature factor at the internal surface present a confidence interval often near to 0.01, a value that shows a good relation among the variables considered. From the validation it emerges that the use of non-homogeneous stratigraphy can often bring the results out of the confidence interval provided by the report. In cases with a significant error it is necessary to have a deeper analysis through further two-dimensional simulations.

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1 INTRODUCTION

It is well known that buildings are responsible for 40% of the global energy consumption and that the construction sector is the field with more possibilities to reduce its energy use.

For this reason the European directives 2002/91/CE and 2010/31/UE impose general rules about the energy efficiency in buildings. Owing to this growth of European norms, which has caused the drawing up of the national ones, the buildings start being more and more efficient and so the thermal bridge influence becomes more and more significant: dispersions due to the thermal bridge can reach 50% of the total energy consumption of a building.

In recent years it has never been developed rules which could be sufficient and exhaustive to evaluate the real influence of a thermal bridge in the building energy balance. For this reason the Energy Department of *Politecnico di Milano* with the support of ANCE and CESTEC has drawn up a thermal bridges abacus. This abacus provides reports with a graphic representation of the thermal bridge schematization and some correlations (based on internal and external dimensions) which allow the assessment of the linear thermal transmittance with their confidence interval and validity fields. These correlations are expressed in function of some parameters, which define the thermophysical and geometrical characteristics of the building elements composing the thermal bridge.

The UNI EN ISO 14683 [N9] says that thermal bridges are building discontinuities which [...]"give rise to changes in heat flow rates and surface temperatures compared with those of the unbridged structure." These two effects are expressed respectively by the linear thermal transmittance and the temperature factor at the internal surface. So the CESTEC-ANCE thermal bridges abacus considers only the first one of these aspects.

This thesis starts from this abacus to develop the correlations of the temperature factor at the internal surface and to validate some abacus reports through real building junctions.

The first step to define these new correlations has been the extrapolation of the results of surface temperature provided by the same simulations used to calculate the linear thermal transmittance. Through these temperature values it has been possible to determine the minimum acceptable value of the temperature factor at the internal surface for each simulation. Then these final results have been unified in correlations, one for each schematization of thermal bridge, based on the same parameters described before.

The second part of this thesis is the validation of some of the abacus reports. For this purpose, it has been decided to validate some representative families of thermal bridge, which are:

- junctions between external wall and pillar;
- projecting corners;
- junctions between external wall and floor.

This validation starts from simulations on real building junctions that correspond to the reference ones. The outputs of these simulations have allowed the evaluation of the linear thermal transmittance and the temperature factor at the internal surface for each validation case. With these values it has been possible to evaluate the mean square error generated by them with reference to the abacus correlations. In this way it is possible to compare the confidence interval obtained through the simulations on thermal bridge schematizations (for the reference thermal bridges abacus), which are characterized by homogeneous layers, and the mean square error generated by simulations on real building junctions, characterized by non-homogeneous layers. The mean square error is also represented by its percentage on the average of the values provided by the real examples simulated.

In conclusion, the following chapters give: an introductive description of all the theoretical aspect taken into consideration in this study in chapter **2**; the calculation procedure for linear thermal transmittance and temperature factor at the internal surface, the final abacus reports and a conclusive evaluation on condensation in chapter **3**; the adopted approach during the validation, its final reports and their evaluation in chapter **4**.

2 THERMAL BRIDGES

2.1 NORMATIVE REFERENCES

In order to evaluate the influence of a thermal bridge in the building energy balance, first of all it's necessary to calculate the thermal transmittance of any constructive element. From this point of view, the normative references are:

- UNI 7357 FA-3 [N11]: this standard introduces a calculation method to determine the thermal need to heat a building and in its annex indicates some rules to obtain the unitary wall thermal transmittance. It considers cases of homogeneities, heterogeneities, variable thicknesses, ventilated air layers, different types of junction (between two similar or different walls, between walls and doors or windows, between internal and external walls, etc.), ground floors and basement walls. The thermal resistance of an homogeneous layer is the ratio between the thickness and the thermal conductivity of the layer itself. The normative reference for thermal conductivities indicated in this standard is the UNI FA 101.
- UNI 10351 [N12]: this norm integrates the UNI FA 101 and gives tabulated values of thermal conductivity and vapour permeability of the most materials on the market.
- UNI 10355 [N13]: this standard gives tabulated values of thermal resistance for non homogeneous elements, such as walls and floors. In its annex it indicates the initial hypothesis used to determine these values and how are considered airspaces and plasters in the calculation method (Finite Element Method).
- UNI EN ISO 10456 [N6]: this norm gives tabulated values of hygrothermal properties for thermally homogeneous building materials and products. It indicates the test conditions and methods to obtain their declared and design values and how to convert tabulated values under other boundary conditions (different temperature, moisture, age and natural convection).
- UNI EN ISO 6946 [N1]: this standard provides rules to obtain the thermal resistance and transmittance of building elements, except windows, curtain walls, ground floors and components which are air permeable. It updates the UNI 7357 FA-3 and introduces the concept of superficial resistance, unheated space thermal resistance (for example roof spaces) and the correction factors for air voids in insulation, mechanical fasteners penetrating an insulation layer and precipitation on inverted roofs.
- UNI EN ISO 10077-1-2 [N3][N4]: these norms introduce rules to obtain the thermal transmittance of windows and doors (with different types of glazing, opaque panels, various types of frame and the additional thermal resistance introduced by different types of closed shutter). With the rules provided by the first part of this norm it is possible to obtain the thermal transmittance of: single, double or coupled windows; single or multiple glazing; windows with shutters and completely glazed doors or doors without glazing. In its annex it indicates tabulated values that have to be introduced in the rules explained over, such as the linear thermal transmittance of frame/glazing junction. The second part of this norm explains the numerical method to calculate the thermal transmittance of frame profiles and the linear thermal transmittance of their junction with glazing or opaque panels. It can also be used to evaluate the thermal resistance of shutter profiles and the thermal characteristics of roller shutter boxes.
- UNI EN ISO 9346 [N2]: this norm is a reference vocabulary to define a lot of the aspects used in studies about the energy balance.

One of the scopes of this thesis is to try to define a complete abacus about the temperature factor at the internal surface, based on a previous abacus about the linear thermal transmittance of some categories of thermal bridges, chosen through an analysis on the market. From this point of view, the normative references are:

- UNI EN ISO 14683 [N9]: this standard deals with simplified methods to determine heat flows through linear thermal bridges which occur at junctions of building elements. It shows how thermal bridges influence the overall heat transfer and it lists the possible methods to determine the linear thermal transmittance. In its annex it provides tabulated values of this for different types of junction of building elements, classified according to their composition, and some calculation examples.
- UNI EN ISO 10211 [N5]: this norm sets out the specifications for a three-dimensional and a two-dimensional geometrical model of a thermal bridge for the numerical calculation of heat flows, in order to assess the overall heat loss from a building or part of it, and minimum surface temperatures, in order to assess the risk of surface condensation. It explains the principles, the construction model and how to obtain the necessary outputs. In its annex it shows how to validate the numerical method, some calculation examples and the outputs determination with more boundary conditions.
- UNI EN ISO 13788 [N7]: this standard gives the calculation methods necessary to obtain the temperature at the internal surface of a building element below which mould growth is likely and the assessment of the risk of interstitial condensation due to water vapour diffusion, with some simplifying assumptions. For this purpose, it defines the temperature factor at the internal surface and provides same calculation examples. In the last annexes it considers additional aspects, such as the condensation on window frames.

2.2 THERMAL BRIDGE DEFINITION

2.2.1 Normative definition

The theme of the energy balance is diffusing a lot in the last period, owing to a greater interest in environmental problems, such as CO_2 emission and greenhouse effect. One of the most important aspect which influences the total dispersion of a building is the thermal bridge. As a consequence, a lot of norms have tried to define it and its effects.

The UNI EN ISO 14683 [N9], norm which provides tabulated values of the linear thermal transmittance, begins introducing the thermal bridge effects: "Thermal bridges in building constructions give rise to changes in heat flow rates and surface temperatures compared with those of the unbridged structure. These heat flow rates and temperatures can be precisely determined by numerical calculation in accordance with ISO 10211. However, for linear thermal bridges, it is often convenient to use simplified methods or tabulated values to obtain an estimate or their thermal transmittance.

The effect of repeating thermal bridges which are part of an otherwise uniform building element, such as wall ties penetrating a thermal insulation layer or mortar joints in lightweight blockwork, needs to be included in the calculation of the thermal transmittance of the building element concerned, in accordance with ISO 6946.

Although not covered by this International Standard, it is worth noting that thermal bridges can also give rise to low internal surface temperatures, with an associated risk of surface condensation or mould growth."

This standard defines linear thermal bridge as a "thermal bridge with a uniform cross section along one of the three orthogonal axes" and indicates the locations in a building envelope in which it is possible to find it:

- at junctions between external elements (corners of walls, wall to roof, wall to floor);
- at junctions of internal walls with external walls and roofs;
- at junctions of intermediate floors with external walls;
- at columns in external walls;
- around windows and doors.

The UNI EN ISO 10211 [N5], as indicated in the UNI EN ISO 14683 introduces the use of numerical methods to evaluate the thermal bridge effects: "Although similar calculation procedures are used, the procedures are not identical for the calculation of heat flows and of surface temperatures.

A thermal bridge usually gives rise to three-dimensional or two-dimensional heat flows, which can be precisely determined using detailed numerical calculation methods as described in this International Standard.

In many applications, numerical calculations based on a two-dimensional representation of the heat flows provide results of adequate accuracy, especially when the constructional element is uniform in one direction."

"This International Standard sets out the specifications for a three-dimensional and a two-dimensional geometrical model of a thermal bridge for the numerical calculation of:

- heat flows, in order to assess the overall heat loss from a building or part of it;
- minimum surface temperatures, in order to assess the risk of surface condensation.

These specifications include the geometrical boundaries and subdivisions of the model, the thermal boundary conditions, and the thermal values and relationships to be used.

This International Standard is based upon the following assumptions:

- all physical properties are independent of temperature;
- there are no heat sources within the building element.

This International Standard can also be used for the derivation of linear and point thermal transmittances and of surface temperature factors."

This norm defines precisely the concept of thermal bridge as a "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, and/or a change in thickness of the fabric, and/or a difference between internal and external areas, such as occur at wall/floor/ceiling junctions."

The UNI EN ISO 13788 [N7] inserts the concept of thermal bridge speaking about the determining parameters that govern surface condensation and mould growth, besides the external climate (air temperature and humidity), that are:

- "the "thermal quality" of each building envelope element, represented by thermal resistance, thermal bridges, geometry and internal surface resistance. The thermal quality can be characterized by the temperature factor at the internal surface, f_{Rsi};
- the internal moisture supply;
- internal air temperature and heating system."

The composition of international standards about environmental problems goes with the drawing up of European directives (such as the 2002/91/CE, modified by the 2010/31/UE [N10]) and national and regional norms (such as the D. Lgs. n.192 [N14], the D. Lgs. n.311 [N15], the D.D.G. n.5796 [N16], the D.G.R. n.VIII/8745 [N17] and the D.P.R. n.59 [N18]).

The D. Lgs. n. 192 and the D. Lgs. n.311 define the thermal bridge as an "insulation discontinuity which can be in correspondence of grafts of structural elements." They also impose that a thermal bridge is correct "when the thermal transmittance of the fictitious wall (part of the wall in correspondence of the thermal bridge) doesn't exceed that one of the wall for no more than the 15%."

The D.G.R. n.VIII/8745 expands a little the national definition: the thermal bridge is "a discontinuity in the thermal characteristics which can be in correspondence of grafts of structural elements (e.g. junction between floor and vertical structures or between vertical structures to each other) or also in presence of particular geometries (edges or corners)."

2.2.2 Thermal bridge description

The concept of thermal bridge is important in the calculation of the thermal dispersions of the building envelope.

The point of reference in this field is the Fourier differential equation, which, solved with hypothesis of one-dimensional flow and steady state, becomes:

$$Q = U \cdot A \cdot \Delta T \quad (W) \tag{2.1}$$

Where:

- Q is the heat flow rate;
- U is the unitary wall thermal transmittance;
- A is the wall surface;
- ΔT is the difference between internal and external air temperatures.

The bases which this rule is constructed on are a lot:

- all the factors are constant during the time;
- the internal and external air temperatures have the same value in every point of the space;
- the materials thermal properties and the surface heat transfer coefficients are independent from the time;
- the walls are plane, extended indefinitely and composed by parallel material layers, which are all different;
- the thermal resistances due to the contact between two layers are null;
- the heat flow is one-dimensional and perpendicular to the plane surfaces delimiting the wall.

These hypothesis aren't so real: in fact, for example, the walls have finite dimensions and are located in the space in different way (e.g. corner) and the materials can't always create perfect and planar layers (e.g. brick wall with plaster joints). So the rule ***(2.1)*** doesn't consider these aspects with consequent errors in the calculation of the thermal dispersions and of the development of the temperature at the internal surface.

This temperature can be calculated equating the total heat flow rate and the heat flow rate in correspondence of the internal surface:

$$T_{si} = T_i - \frac{U}{h_i} \cdot (T_i - T_e) \quad (K) \tag{2.2}$$

Where:

- T_{si} is the temperature at the internal surface;
- T_i and T_e are internal and external air temperatures;
- h_i is the heat transfer coefficient at the internal surface.

The development of the value provided by this rule is shown in the following picture with a dotted line.

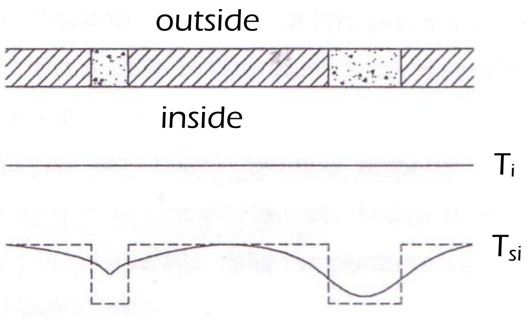


Figure 2.1 - Example of development of the temperature at the internal surface

This development isn't so real because temperature differences not equal to zero in correspondence of a constructive element different from the wall itself determine a transverse heat flow. This aspect contradicts the hypothesis of an heat flow one-dimensional and perpendicular to the wall surface. The presence of a transverse heat flow generates a less difference between the temperature at the internal surface in correspondence of the wall and of the discontinuity element, but it increases the length of the zone interested by the thermal bridge. The real temperature development is described by a continuous line in the picture before. As it is possible to see, in correspondence of the thermal bridge the isotherms aren't parallel to each other: they have a curvilinear development more accentuated when the effect of the thermal bridge is stronger. Owing to the fact that the heat flow is always perpendicular to the isotherms, in correspondence of the thermal bridge there is a concentration of the dispersions. These zones are characterized by a surface cooling and a loss of the wall insulating power with consequent variations in the energy balance.

So the thermal bridge is a constructive discontinuity that causes a two-dimensional heat flow. A constructive discontinuity is a part of the building which presents thermal characteristics significantly different from that of the near ones.

In a building it is possible to find three different types of discontinuity: insulation one, material one (e.g. an armed concrete pillar in a brick wall) and geometric one (e.g. the corners without pillar or junctions between internal and external walls). Naturally it is possible to find the last two ones together (e.g. corners with an armed concrete pillar). The value of lost heat flow due to thermal bridge can reach the 30% of the total lost heat flow.

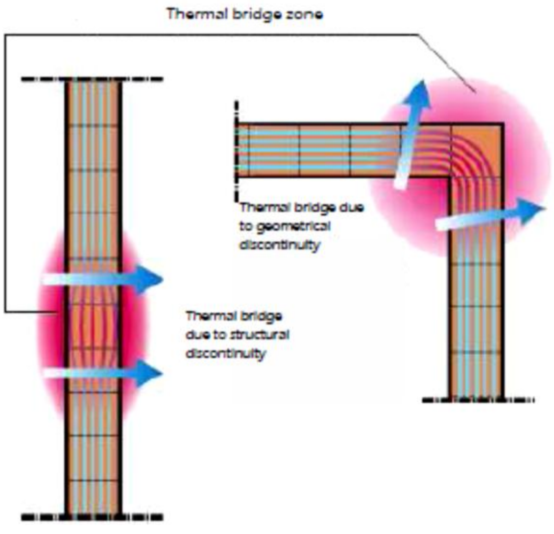


Figure 2.2 – Examples of structural an geometrical discontinuities [W10]

The critical points in which it is possible to find a thermal bridge are:

- junctions between wall and pillar or beam;
- ground floors;
- junctions between wall and window or door;
- junctions between internal and external walls;
- balconies;
- rolling shutter boxes.

The thermal bridges can be represented by the linear thermal transmittance Ψ. This factor indicates the loss of heat flow for a unitary length of the thermal bridge and for a unitary difference between internal and external air temperatures.

Ψ is calculated comparing the situation with and without thermal bridge. As said before in ***(2.1)*** the theoretical heat flow rate is:

$$Q_{theor} = U \cdot A \cdot \Delta T \quad (\, W \,)$$

Whereas the real value is obtained by simulations through a two-dimensional calculation code.

Ψ derives from the difference between these two values:

$$\Psi = \frac{(Q_{real} - Q_{theor})}{\Delta T \cdot l} \quad (\frac{W}{m \cdot K}) \qquad \textit{(2.3)}$$

Where:

- Q_{real} is the real heat flow rate;
- l is the development of the thermal bridge.

Through the rule provided before, it is possible to write:

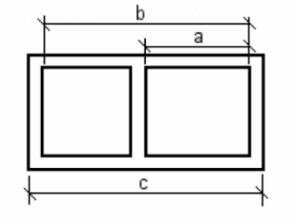
$$Q_{real} = Q_{theor} + \Psi \cdot l \cdot \Delta T \ = \Delta T \ \cdot (U \cdot A + \Psi \cdot l) = \Delta T \ \cdot H_T \quad (\, W \,) \qquad \textit{(2.4)}$$

Where H_T is transmission heat transfer coefficient.

So to determine the linear thermal transmittance it is important to know precisely the thermal properties of each building element.

Now it is provided an example of calculation of thermal bridge applied on a corner without pillar.

One of the first questions is what dimensions to consider in the procedure. The UNI EN ISO 13789 [N8] indicates three different types of dimensions:



Key

a internal dimension

b overall internal dimension

c external dimension

Figure 2.3 - UNI EN ISO 13789 [N8], Figure 1

Considering external dimension and the contribution of the only walls, the transmission heat transfer coefficient is:

$$H_T = A_{1,E} \cdot U_1 + A_{2,E} \cdot U_2 \qquad (\frac{W}{K}) \qquad (2.5)$$

Where:

- $A_{1,E}$ and $A_{2,E}$ are the surfaces of the two walls of the corner based on external dimensions;
- U_1 e U_2 are the thermal transmittances of the two walls.

It is evident that this calculation isn't correct because the "corner zone" is considered twice. So it is necessary to add the edge contribution through Ψ:

$$H_T = A_{1,E} \cdot U_1 + A_{2,E} \cdot U_2 + \Psi \cdot l \qquad (\frac{W}{K}) \qquad (2.6)$$

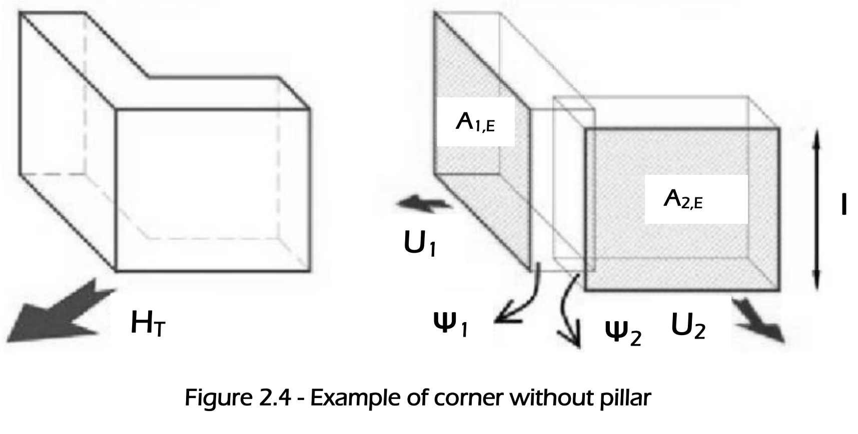


Figure 2.4 - Example of corner without pillar

So, using external dimensions, the thermal bridge characterized by a corner without pillar (geometrical discontinuity) is negative in order to reduce H_T. Whereas if in correspondence of the junction between the walls there were a pillar (material discontinuity), this thermal bridge would become positive.

This reasoning is different using internal dimensions: in this case the thermal bridge is always positive because the "corner zone" is never considered.

Of course H_T based on external dimensions and H_T based on internal dimensions are equal. This aspect points out that the linear thermal transmittance value has to be consistent with the chosen dimensions system. The relation between the two values is:

$$\Psi_E = \Psi_I - s_1 \cdot U_1 - s_2 \cdot U_2 \qquad \left(\frac{W}{m \cdot K}\right) \qquad (2.7)$$

Where:

- Ψ_E is the linear thermal transmittance based on external dimensions;
- Ψ_I is the linear thermal transmittance based on internal dimensions;
- s_1 e s_2 are the thicknesses of the two walls of the corner.

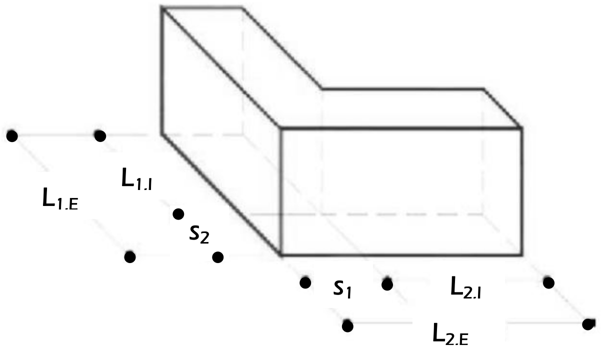


Figure 2.5 - Scheme of internal and external dimensions of a corner

In case of a planar junction internal and external dimensions are equal.

When a thermal bridge is in correspondence of the border between two different thermal zones (e.g. junction between a floor and an external wall) it can be halved. Of course this is a simplifying criterion; it is possible to do a lot of considerations about this argument: the thermal bridge contribution can be divided in different ways, such as on the basis of the thermal transmittance values of the different building elements in the junction or on their transmission heat transfer coefficient.

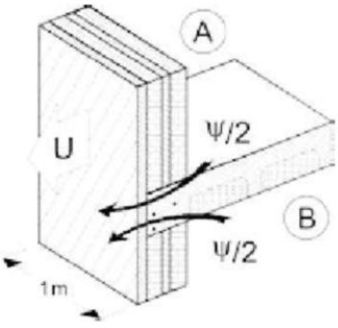


Figure 2.6 - Subdivision of the thermal bridge in two parts

The evaluation of the thermal bridge is becoming more and more important because with the modern performing buildings the influence of discontinuity elements is very high (it can be about 50% of the total thermal dispersion). Above all this evaluation is necessary to respect normative prescriptions.

For example, the D. Lgs. n.311 [N15] imposes that:

- The total thermal dispersion is less than EP_i, which is the index of energy performance for heating air conditioning: the dispersions caused by thermal bridges are part of the total transmission dispersion of a building;
- There isn't superficial condensation: the thermal bridges determine a low surface temperature, which can be less than dew-point one and so it can cause superficial condensation;
- The building elements thermal transmittance is less than the limit imposed by this norm for each type of opaque element, indicated with U_{lim}: these limits are referred to a condition of correct thermal bridge; when the thermal bridge isn't correct the average between the element thermal transmittance and the fictitious wall one has to be less than the limit value.

This comparison is feasible when it is possible to identify the fictitious wall: this happens in case of planar junction with only material discontinuities, when the stratigraphy of the discontinuity element has layers perpendicular to the heat flow (e.g. junction between wall and pillar or between external wall and floor when this is homogeneous). For junctions between roof and external wall or corners, whereas, the problem is that there is a geometrical discontinuity (the stratigraphy and the heat flow aren't perpendicular between them) and so in this case is difficult to determine thermal transmittance in correspondence of the thermal bridge.

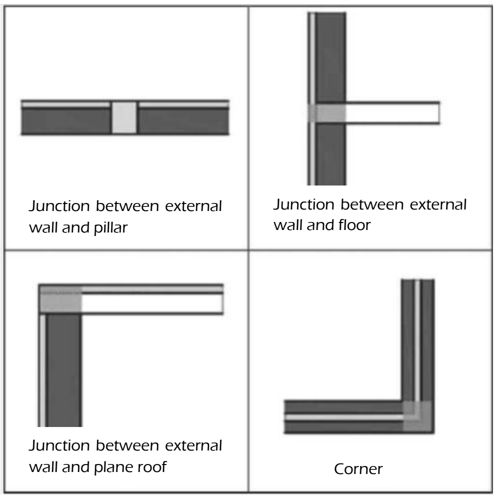


Figure 2.7 - Identification of the fictitious wall

In general the rules are:

$$U_{TB} \leq U + 15\% \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad (2.8)$$

$$U < U_{lim} \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad (2.9)$$

Or with incorrect thermal bridge:

$$U_{ave} = \frac{U \cdot A + U_{TB} \cdot A_{TB}}{A + A_{TB}} < U_{lim} \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad (2.10)$$

Where:

- U_{TB} is the fictitious wall thermal transmittance;
- U is the wall thermal transmittance;
- U_{lim} is the limit value of thermal bridge imposed by D. Lgs. n.311 [N15] referred to a condition with correct thermal bridges;
- U_{ave} is the thermal transmittance value that corresponds to the weighted average between U and U_{TB};
- A is the wall surface;
- A_{TB} is the fictitious wall surface.

When it isn't possible to identify the fictitious wall U_{ave} is:

$$U_{ave} = \frac{\sum U_i \cdot A_i + \sum \Psi_j \cdot l_j}{A_{tot}} = \frac{\sum H_i}{A_{tot}} = \frac{H_T}{A_{tot}} \quad (\frac{W}{m^2 \cdot K}) \qquad \textit{(2.11)}$$

Where:

- $\sum U_i \cdot A_i$ is the sum of products between the thermal transmittance and the surface of each building element, indicated with subscript i;
- $\sum \Psi_j \cdot l_j$ is the sum of products between the linear thermal transmittance and the length of each thermal bridge, indicated with subscript j;
- A_{tot} is the total dispersant surface.

In general it is better to use this rule because the rule ***(2.10)*** considers the wall and the thermal bridge as two parts totally separated with a perpendicular heat flow, whereas they really interact and the heat flow is two-dimensional with a greater thermal dispersion: calculating the transmission heat transfer coefficient the relation between the wall and the thermal bridge is taken into consideration through Ψ.

Comparing the H_T based on external dimensions and H_T based on fictitious wall:

$$U_{TB} \cdot A_{TB} = U \cdot A_{TB} + \Psi \cdot l \quad (\frac{W}{m^2 \cdot K}) \qquad \textit{(2.12)}$$

$$U_{TB} = U + \Psi \cdot \frac{l}{A_{TB}} = U + \frac{\Psi}{s} \quad (\frac{W}{m^2 \cdot K}) \qquad \textit{(2.13)}$$

Where:

- Ψ is the linear thermal transmittance of the thermal bridge;
- l is the development of the thermal bridge;
- s is the thickness of the incident wall.

The meaning of this rule is: the thermal transmittance increase is equal to the thermal bridge "spread" on the fictitious wall.

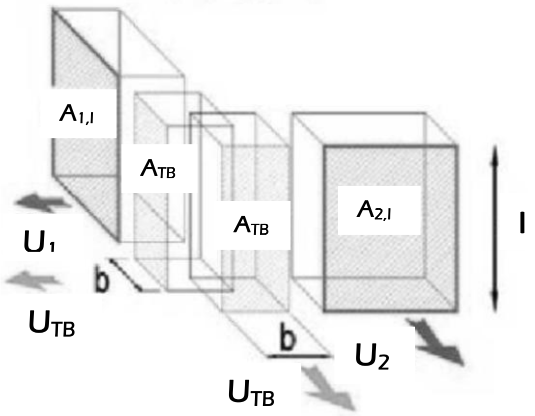


Figure 2.8 - Fictitious wall for a corner

2.2.3 Thermal bridge effects

The UNI EN ISO 14683 [N9] says that the two most important effects of a thermal bridge are:

- a change in the heat flow rate;
- a change in the internal surface temperature.

The first one can be calculated using numerical methods, such as Finite Element Method (FEM) and Finite Volume Method (FVM), or with simplified rules, provided by the normative references or by national catalogues.

The second one involves a verification of the hygrothermal behaviour of the building element. This verification is fundamental either during the project to identify the correct stratigraphies or in improvement intervention for insulation to understand the right position and thickness to adopt.

The non-homogeneous temperature distribution in correspondence of the structural elements can cause the growth of internal tensions with a consequent degradation of the materials.

The surface temperature decrease determines a local discomfort when the difference between the internal air temperature and the that of surface is more than 3K. When the temperature at the internal surface becomes less than that of the dew-point and there is the condensation with mould growth the hygienic conditions decrease a lot: the mould releases toxins and spores that can be breathed by people. In this case it is used the following expression: "Sick Building Syndrome", concept that unifies all the indoor pollution problems, both microbiological and chemical or physical.

Figure 2.9 - Superficial condensation photo [W11]

A low value of the surface temperature can cause two types of condensation: the superficial and the interstitial.

The interstitial condensation is due to the vapour diffusion inside the building element layers because of a difference between internal and external pressures. This passage doesn't create problems until the vapour meets a layer with a surface temperature less than the dew-point one. In this case it is important to verify that the condense accumulated during the heating period is disposed during the cooling period.

The condense permanence inside a building element determines a fast decrease of the thermal resistance and so this process is amplified continuously.

In this study it is analyzed the superficial condensation, which is strongly linked with the internal conditions and the insulation level of the building elements, in fact the presence of an insulation increases a lot the surface temperature. To exclude the possibility of this type of condensation it is important to maintain the temperature at the internal surface less than the dew-point one T_{dp}:

$$T_{si} > T_{dp} \quad (K) \qquad (2.14)$$

With an hypothesis of one-dimensional heat flow, as said before, the surface temperature is:

$$T_{si} = T_i - \frac{U}{h_i} \cdot (T_i - T_e) \quad (K)$$

In this rule, introducing T_{dp} as T_{si}, it is possible to obtain the maximum acceptable thermal transmittance:

$$U_{max} = \frac{T_i - T_{dp}}{T_i - T_e} \cdot h_i \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad (2.15)$$

So the additional thermal resistance R_{add} offered by the insulation is:

$$\frac{1}{U_{max}} - \frac{1}{U} = R_{add} = \frac{s_{ins}}{\lambda_{ins}} \quad \left(\frac{m^2 \cdot K}{W}\right) \qquad (2.16)$$

Where:

- U is the thermal transmittance of the building element;
- s_{ins} is the insulation thickness;
- λ_{ins} is the insulation thermal conductivity.

In this study, the superficial condensation has been evaluated through the temperature factor at the internal surface:

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e} \quad (-) \qquad (2.17)$$

Where:

- T_{si} is the temperature at the internal surface;
- T_i and T_e are the internal and external temperatures.

This coefficient is explained better in the chapter **2.4**.

The solutions to reduce the effects of the thermal bridges are: ensuring a great insulation level (e.g. through an insulation layer outside of the structural elements, such as pillar or beam, or even better through an insulation layer that covered totally the outside surface of the building) and a right ventilation, that decreases the internal relative humidity. The ventilation can be natural or forced.

Generally the limit values for internal relative humidity are 40% and 60%: a relative humidity less than 40% can irritate the respiratory system and promote infections; whereas one greater than 60% can cause the mould growth with a possible risk of asthma.

2.3 LINEAR THERMAL TRANSMITTANCE ABACUS DESCRIPTION

The study exposed in this thesis starts from a previous analysis on linear thermal transmittance of a lot of thermal bridge schematizations.

This previous analysis began with a large research about the thermal bridges in the market (125 types were found), which then have been examined by ANCE in order to determine the most widespread (47 types). These ones have been divided in some categories, according to the UNI EN ISO 14683 [N9].

The typological families studied are the following ones:

- junction between wall and pillar;
- concave corner;
- concave corner with pillar in correspondence of the junction;
- projecting corner;
- projecting corner with pillar in correspondence of the junction;
- junction between wall and plane roof;
- junction between wall and floor;
- junction between external and internal walls;
- balcony;
- junction between wall and window or door;
- compluvium;
- ridge.

From these initial selection and classification it has been possible to define every thermal bridge schematization and so to plan every simulation. The calculation method applied (two-dimensional Finite Volume simulation through Fluent software) has been verified through the example 2 of the Annex A of the UNI EN ISO 10211 [N5].

2.3.1 Adopted approach for calculation

In order to simulate every type of the selected thermal bridges it has been necessary to choose typologies of wall, floor and roof that have to be usual in constructions and representative of the different technologies in the market.

In this study it has been considered walls with or without insulation: in case of insulated walls the insulation position can be either inside or outside or in the middle with three different thicknesses: 5 cm, 10 cm or 15 cm. In some particular cases, such as corners, other thicknesses have been taken into consideration, for example 20 cm.

It's important to consider different insulation positions because, while in the thermal transmittance calculation its position is negligible, whereas this aspect is fundamental in two-dimensional thermal flow calculation.

Another differentiation has been the bricks density: three different densities have been taken into consideration: 1800 kg/m^3, 1200 kg/m^3 or 760 kg/m^3. The references for the hygrothermal properties values have been the UNI 10351 [N12], the UNI 10355 [N13] and the UNI EN ISO 10456 [N6]. In order to obtain a large variety of thermal transmittance in every simulation, for any brick density three different cases with different thicknesses of bricks and insulation (U_{max}, U_m, U_{min}) have been studied: U_{max} presents a brick thickness of 25 cm and an insulation thickness of 5 cm, U_m presents a brick thickness of 40 cm and an insulation thickness of 10 cm, U_{min}

presents a brick thickness of 45 cm and an insulation thickness of 15 cm. The values obtained have been reported in the ANNEX B (chapter **6.2**). In the case with further insulation thicknesses other thermal transmittance have been studied.

Some simulations have demonstrated the possibility of homogenizing some wall layers (the layers which haven't insulating properties) through the introduction of an equivalent thermal conductivity.

Armed concrete pillars and beams, as floors and roofs, have been studied with or without insulation (the insulation position can be inside or outside).

These input data have been inserted in the simulations to obtain the final value of linear thermal transmittance for every case of study. Then these final results have been unified in correlations, which allow to obtain the linear thermal transmittance value for every type of thermal bridge. These correlations have been enveloped in function of some parameters, such as thermal transmittance (U) or equivalent thermal conductivity (λ_{eq}) of the principal elements, non dimensional transmittance (U*) and non dimensional length (L*).

The final abacus has been structured in reports which contain a graphic representation of the thermal bridge into consideration, the estimated correlation with the definition of the parameters inserted in, the validity range of these parameters and the confidence interval.

The correlations elaborated in this abacus can be used for thermal bridges, which have constructive elements with properties inside the validity range indicated in the relative report. For other cases these ones can give only an idea of a possible result, but the indicated tolerances aren't guaranteed.

2.3.2 Parameters definition

As mentioned previously, the correlations have been enveloped in function of different parameters, which are explained in the following paragraphs.

Thermal transmittance

The references to obtain walls and windows thermal transmittance are respectively the UNI EN ISO 6946 [N1] and the UNI EN ISO 10077-1-2 [N3][N4].

The first one indicates the calculation method to obtain thermal resistance of every plane element with parallel homogeneous layers perpendicular to the thermal flow:

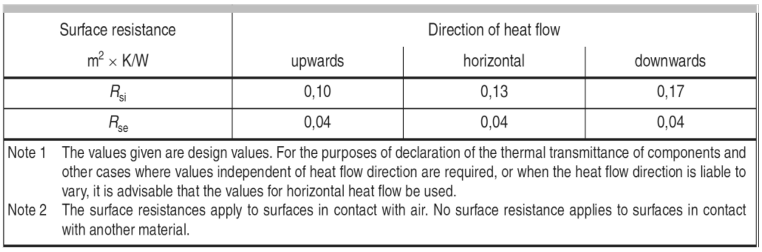
$$\frac{1}{U} = R_T = R_{si} + R_1 + R_2 + \ldots R_n + R_{se} \qquad \left(\frac{m^2 \cdot K}{W}\right) \qquad (2.18)$$

Where:

- R_{si} and R_{se} are internal and external surface resistances;
- R_1, R_2 … R_n are the design thermal resistances of each layer, calculated as the ratio between thickness and thermal conductivity of each layer itself.

In case of internal elements or of elements situated between the internal space and an unheated space, R_{si} has to be applied on both element fronts.

R_{si} and R_{se} have to be taken from the UNI EN ISO 6946 [N1] in function of the heat flow direction. However it's possible to applied the R_{si} relative to an horizontal direction of the heat flow on every surface taken into consideration when the direction of the heat flow is uncertain or when a whole building is analyzed with only one calculation. In ANNEX C (chapter **6.3**) it is possible to find the surface resistance values considered in this case of study



Surface resistance $m^2 \times K/W$	Direction of heat flow upwards	 horizontal	 downwards
R_{si}	0,10	0,13	0,17
R_{se}	0,04	0,04	0,04

Note 1 The values given are design values. For the purposes of declaration of the thermal transmittance of components and other cases where values independent of heat flow direction are required, or when the heat flow direction is liable to vary, it is advisable that the values for horizontal heat flow be used.

Note 2 The surface resistances apply to surfaces in contact with air. No surface resistance applies to surfaces in contact with another material.

Figure 2.10 - UNI EN ISO 6946 [N1], table 1

In this study the UNI EN ISO 10077-1-2 [N3][N4] aren't taken as reference for the calculation method, but to extrapolate the thermal transmittance range to consider. Two different types of frame are considered: a wooden frame with a thermal transmittance of 1,9 W/m^2K and a metallic frame with a thermal transmittance of 5,5 W/m^2K. Using the inverse relation, it's possible to obtain the equivalent thermal conductivity:

$$R_f = \frac{1}{U_f} = R_{si} + \frac{s_f}{\lambda_{eq,f}} + R_{se} \qquad \left(\frac{m^2 \cdot K}{W}\right) \tag{2.19}$$

$$\lambda_{eq,f} = \frac{s_f}{\frac{1}{U_f} - R_{si} - R_{se}} \qquad \left(\frac{W}{m \cdot K}\right) \tag{2.20}$$

The equivalent thermal conductivity values obtained are:

- $\lambda_{eq,f}$ = 0.168 W/(m * K) for wooden frame;
- $\lambda_{eq,f}$ = 5.077 W/(m * K) for metallic frame.

From the rules indicated before, it's possible to understand that the frame is considered as composed by full material, without cavities, with an equivalent thermal conductivity equal to the ones indicated before. This is real for a wooden frame, but not for a metallic one, but it doesn't determine an excessive error because this study isn't interested in the temperature development inside the metallic frame, but in the influence of the frame presence on the wall.

Wall equivalent thermal conductivity

The equivalent thermal conductivity is a value which represents a weighted average of the thermal conductivity of every layer, except the insulation:

$$\lambda_{eq} = C \cdot L \qquad \left(\frac{W}{m \cdot K}\right) \tag{2.21}$$

Where:

- C is the wall conductance, which is the inverse of the sum of the ratio between thicknesses L_i and thermal conductivities λ_i of each layer, excluding insulation:

$$C = \frac{1}{\sum \frac{L_i}{\lambda_i}} \quad \left(\frac{W}{m}\right) \tag{2.22}$$

- L is the wall thickness, excluding insulation:

$$L' = \sum L_i \quad (m) \tag{2.23}$$

Non dimensional thermal transmittance

The non dimensional thermal transmittance represents, in presence of a pillar or of a beam, the ratio between the pillar (or beam) thermal transmittance and that one of the wall:

$$U^* = \frac{U_P}{U_W} \quad (-) \tag{2.24}$$

The pillar (or beam) thermal transmittance is calculated as the inverse of the total thermal resistance, but the direction, which the calculation is applied on, depends on every case: for example in a corner it is calculated on the pillar diagonal, whereas for the beam a significant section is defined in every case of study (generally a thickness equal to that one of the wall is applied).

Non dimensional length

The non dimensional length represents the ratio between the pillar (or beam) characteristic length (defined every times) and the wall thickness:

$$L^* = \frac{L_P}{L_W} \quad (-) \tag{2.25}$$

2.3.3 Calculation dominion

The simulations have been done considering one meter of wall from the discontinuity element in horizontal or vertical direction. This choice has been applied according to the UNI EN ISO 10211 [N5] and has been verified through the calculation method: after one meter from the discontinuity element the isotherms are parallel, the heat flow is one-dimensional and perpendicular to the wall surface and so the thermal bridge influence is negligible. The following picture shows this aspect clearly.

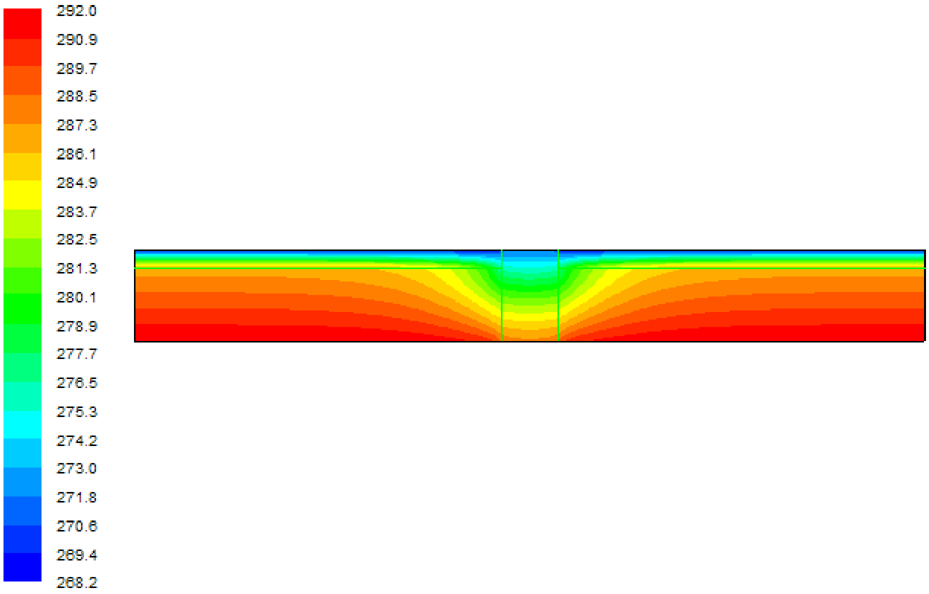


Figure 2.11 - Temperature profile (junction between wall and pillar, Um, l=2m)

On the contrary, the following picture reports the temperature profile with one meter of wall on both side of the discontinuity element:

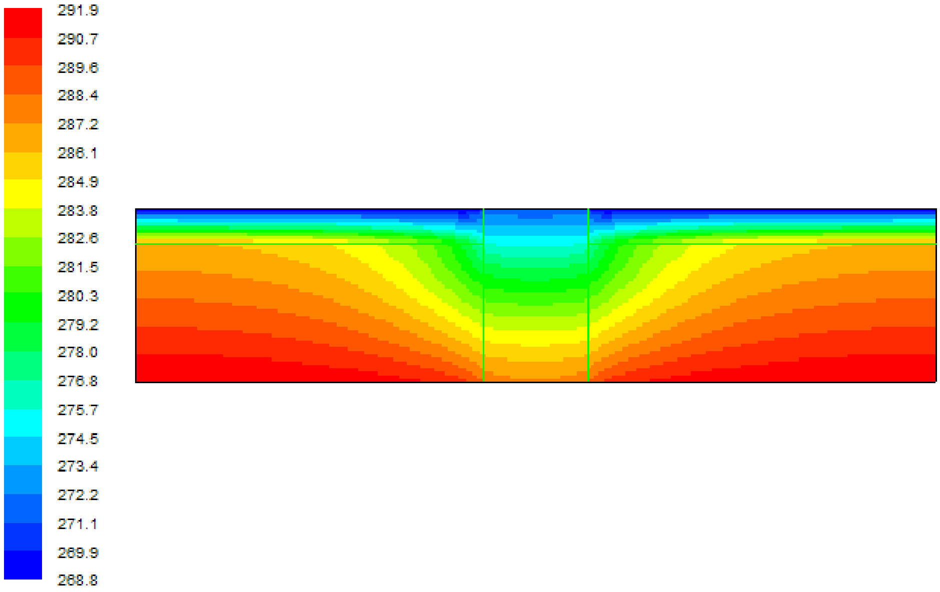


Figure 2.12 - Temperature profile (junction between wall and pillar, Um, l=1m)

A graphic representation explains this aspect better:

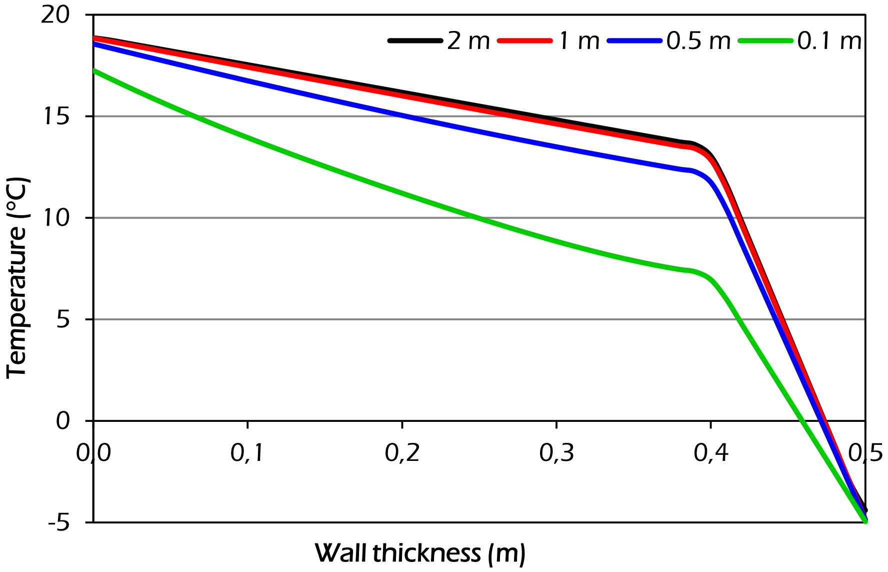


Figure 2.13 - Temperature profile in different sections of the wall

If it were necessary to analyze a thermal bridge with different dimensions from the ones explained before, the correlations could be applied, but it's fundamental that the parameters are inside the validity field indicated in the relative report.

2.4 TEMPERATURE FACTOR AT THE INTERNAL SURFACE

2.4.1 Temperature factor at the internal surface definition

The temperature factor at the internal surface is defined by the UNI EN ISO 13788 [N7] as "the difference between the temperature of the internal surface and the external air temperature, divided by the difference between the internal air temperature and the external air temperature, calculated with a surface resistance at the internal surface R_{si}":

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e} \quad (-)$$

In order to create a reference abacus it is better to refer to the minimum acceptable value:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} \quad (-) \qquad (2.26)$$

This norm introduces this factor to explain the thermal quality of each building element represented by thermal resistance, thermal bridges, geometry and internal surface resistance.

If internal and external air temperature values are considered constant, as in the design hypothesis of this study (T_i=20°C e T_e= -5°C), this factor allows to evaluate the thermal bridge influence on the temperature at the internal surface and so on the superficial condensation because $T_{si,min}$ is in correspondence of the thermal bridge. The less is $T_{si,min}$ the less is f_{Rsi} and so it means that superficial condensation is more likely.

As declared by this norm the calculation method to obtain the temperature factor at the internal surface is provided by the UNI EN ISO 10211 [N5]. In this study, the simulation are enveloped through a calculation method which corresponds with the conditions imposed by this international standard (case 2-Annex A). The validation of the calculation code is reported in the CESTEC-ANCE thermal bridges abacus.

2.4.2 Calculation of the minimum acceptable temperature factor at the internal surface

The UNI EN ISO 13788 [N7] says that "To avoid mould growth the relative humidity at the surface should not exceed 0,8 for several days" and so it provides a calculation method to determine the minimum acceptable temperature at the internal surface.

The first step in achieving this value is to identify external conditions, which are resumed in the following table:

T_e	$p_{v,e}$	$p_{vsat,e}$	φ_e
(°C)	(Pa)	(Pa)	(%)
-5	407	407	100

Table 2.1 – External conditions for condensation evaluation

According to the design hypothesis, it has been assumed that T_e = -5°C and φ_e =100%, with:

$$\varphi_e = \frac{p_{v,e}}{p_{vsat,e}} \cdot 100 \quad (\%) \qquad (2.27)$$

And so the vapour pressure $p_{v,e}$ became equal to $p_{vsat,e}$, which has been determined through the following relation [B3]:

$$p_{vsat} = e^{\frac{C_1}{T}+C_2+C_3\cdot T+C_4\cdot T^2+C_5\cdot T^3+C_6\cdot \ln(T)} \quad (Pa) \qquad (2.28)$$

Where:

- C_1=-5800,2206
- C_2=1,3914993
- C_3=0,048640239
- C_4=0,000041764768
- C_5=-0,000000014452093
- C_6=6,5459673
- T is the temperature into consideration, expressed in K.

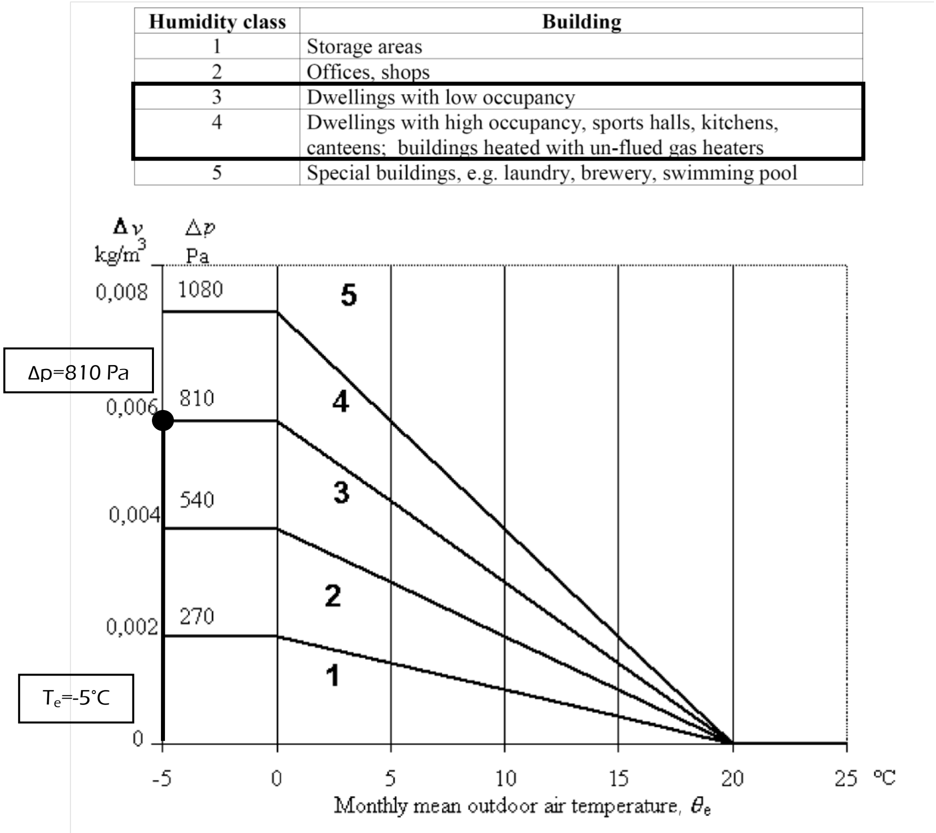
From the values reported in the first table it's possible to evaluate internal conditions, which have been reported in the following table:

T_i	$p_{v,i}$	$p_{vsat,i}$	ϕ_i
(°C)	(Pa)	(Pa)	(%)
20	1298	2365	54.88

Table 2.2 – Internal conditions for condensation evaluation

As the external air temperature, also the internal air temperature T_i has been assumed constant according to design hypothesis (T_i =20°C).

To obtain $p_{v,i}$ is is necessary to know the difference between internal and external vapour pressure Δp, whose values are provided by the Annex A of the UNI EN ISO 13788 [N7] in function of the humidity class of the building and of the external air temperature. In the cases presented in this study the most widespread type of building are dwellings with low or high occupancy. Δp value has been multiplied by a coefficient of 1.1 to provide a safety margin.



Humidity class	Building
1	Storage areas
2	Offices, shops
3	Dwellings with low occupancy
4	Dwellings with high occupancy, sports halls, kitchens, canteens; buildings heated with un-flued gas heaters
5	Special buildings, e.g. laundry, brewery, swimming pool

Figure 2.14 - UNI EN ISO 13788 [N7], Annex A, figure A.1

Using the relations indicated before for $p_{vsat,e}$ *(2.28)* and for φ_e *(2.27)*, it has been possible to calculate $p_{vsat,i}$ and φ_i.

The limit value of saturated vapour pressure $p_{vsat,}(T_{si})$ has been obtained dividing the internal vapour pressure $p_{v,i}$ for the limit of 0.8:

$p_{vsat}(T_{si,min})$	$T_{si,min}$	T_i	T_e	$f_{Rsi,min}$
(Pa)	(°C)	(°C)	(°C)	(-)
1622.50	14.07	20	-5	0.76

Table 2.3 – Minimum acceptable temperature factor at the internal surface

With this values of $p_{vsat}(T_{si,min})$ it has been possible to obtain $T_{si,min}$, inverting *(2.28)*, and then $f_{Rsi,min}$, through*(2.26)*.

Using an ASHRAE[3] diagram, it is possible to see that the intersection between the condensation line determined by $T_{si,min}$=14.07°C and T_i=20,00°C gives a value of φ_i near 70%.

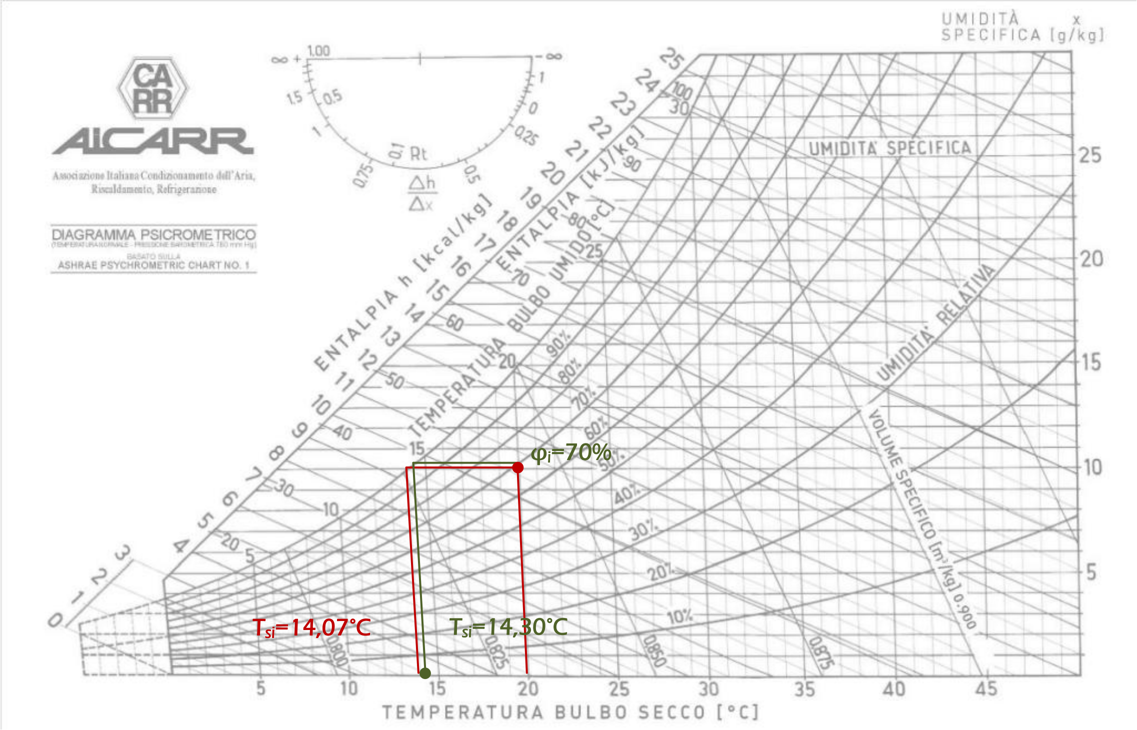


Figure 2.15 - Evaluation through an ASHRAE diagram

Owing to the low precision of the values taken into consideration and the assumed design hypothesis, it has been chosen a φ_i=70% with a $T_{si,min}$=14.30°C. So the minimum acceptable temperature factor at the internal surface is:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} = \frac{14.3 - (-5)}{20 - (-5)} = 0.77 \quad (-)$$

---

[3] ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.
AICARR: Associazione Italiana Condizionamento dell'Aria, Riscaldamento e Refrigerazione.

2.5 NUMERICAL METHODS AND PROGRAMS USED

2.5.1 Finite Volume Method (FVM) description

The Finite Volume Method (FVM) is a method for solving partial differential equations in the form of algebraic equations. Similar to the finite difference method (FDM) and to the finite element method (FEM), it is based on a discretization of the problem through a meshed geometry, but while the finite difference method uses derivative approximations, the finite volume method, as the finite element method, uses an approximation of the initial continuous domain. "Finite Volume" stands for the small volume surrounding each node point on a mesh and it's constant during the time.

In the FVM, volume integrals in a partial differential equation that contains a divergence term are converted to superficial integrals, through divergence theorem. These terms are then considered as flows at the finite volume surfaces. Because the flow entering in a given volume is the same of the one exiting from the adjacent volume, this method is conservative.

An advantage of this method is that it is possible to use it for unstructured meshes: in fact, for discretization of the conservative laws, it doesn't take into account mesh dimensions. Whereas these are important for the flow evaluation. Furthermore, the FVM is preferable to the other methods because the boundary conditions can be applied not invasively: in fact the variables values are defined inside the volume element, and not at nodes or surfaces.

To explain this method it is possible to consider the general conservation law problem:

$$\frac{\partial u}{\partial t} + \nabla \cdot f(u) = \Psi \qquad (2.29)$$

Where:

- u represents the vector of state;
- f is the correspondent flow tensor;
- Ψ is the variation of u owing to external sources.

So it is possible to divide the total volume V in a lot of small finite volume v_i (control volumes) and to apply a volume integral on the conservation law for each one:

$$\int_{v_i} \frac{\partial u}{\partial t} dv + \int_{v_i} \nabla \cdot f(u) dv = \int_{v_i} \Psi dv \qquad (2.30)$$

The first term, inverting integral and derivative (v_i is fixed in space), becomes a volume average, whereas the second one becomes a surface integral, through the divergence theorem. Ψ is assumed as a constant.

$$v_i \cdot \frac{d\overline{u_i}}{dt} + \oint_{S_i} f(u) \cdot n\, dS = v_i \cdot \overline{\Psi_i} \qquad (2.31)$$

Where:

- S_i represents the total external surface of the finite volume;
- n is the unit vector normal to the external surface and pointing outward.

Finally the final equation is:

$$\frac{d\bar{u}_i}{dt} + \frac{1}{v_i} \cdot \oint_{S_i} f(u) \cdot n \, dS = \bar{\Psi}_i \qquad (2.32)$$

The interpretation of this equation is simple: the temporal variation of the volume average of u is equal to the rate of transport of u through the external surface by flow tensor with the contribution of external sources.

The discretization of the total volume can be cell-centered or vertex-centered. In the first one, shown in the left side of the **Figure 2.16**, the triangles themselves serve as control volumes and the variables are located in a point inside the finite volume, which is called node. This solution can appear logical, but it presents a disadvantage: to apply boundary conditions on the volume edge it is necessary to use particular devices because there aren't any nodes on it. The vertex-centered discretization, shown in the right side of the **Figure 2.16**, solves this problem: control volumes are formed as a geometric dual to the triangle complex. In particular case of study with a lot of variables both solutions are used together: in this case the solution is called as staggered grid. It is possible to use interpolation to obtain values of the intermediate points.

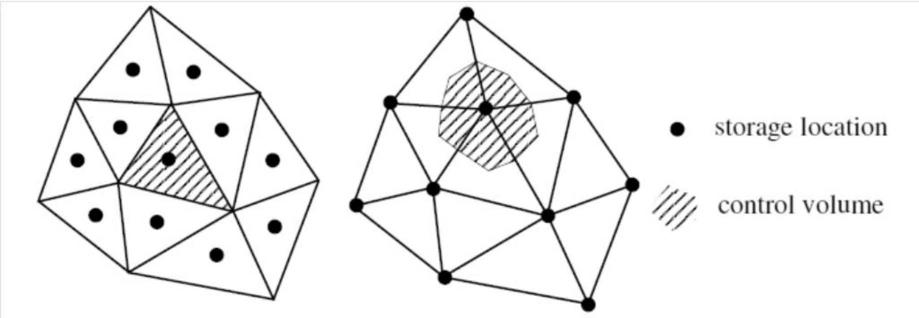


Figure 2.16 - Cell-centered solution on the left and vertex-centered solution on the right [W4]

2.5.2 Finite Element Method (FEM)description

The Finite Element Method (FEM) is a numerical method used to solve approximately problems described by partial differential equations, transforming these ones in algebraic equations. This method belongs to the Galerkin Method class, that starts from the weak formulation of a differential problem.

One of the FEM principal characteristics is the discretization of the initial continuous domain in a discrete domain through a mesh based on primitives (finite elements) characterized by a simple shape (triangle and quadrilateral for two-dimensional dominions, tetrahedron and hexahedral for tridimensional dominions). The definition of the model geometry that idealizes the real element happens through the collocation of a number of nodes able to describe the real structure. It is possible to use interpolation to obtain values of the intermediate points.

To explain this method it is possible to consider the heat stationary equation:

$$f(x) = -\nabla \cdot [k(x) \cdot \nabla \cdot T(x)] \qquad (2.33)$$

The main idea is to approximate, for every element characterized by the simple shape, the exact solution T(x), written in the weak formulation, with a continuous envelop based on a linear combination of local functions called *base functions* or *shape functions* Φ_j.

$$T(x) \approx \hat{T}(x) = \sum_{j=1}^{M} T_j \cdot \Phi_j\,(x) \qquad (2.34)$$

The *shape functions* choice is fundamental in this method. In general they are polynomial in pieces and so the solution becomes a linear function in pieces.

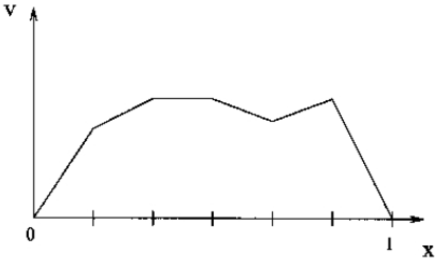


Figure 2.17 - Example of a shape function [W15]

The coefficient number that characterizes the solution depends on the degree of the chosen polynomial. This last one regulates the solution precision.

As said before the solution found through FEM is an approximate solution. A rule to reduce the difference between this solution and the real one is the weighted residues method, which imposes that:

$$\int R \cdot W_i dS = 0 \qquad (2.35)$$

$$R = \nabla \cdot [k(x) \cdot \nabla T(x)] + f(x) \qquad (2.36)$$

Where:

- $W_i(x)$ are the weight function;
- R are the residues.

Another aspect to consider is that the approximate solution has to satisfy the boundary condition also. In this case Dirichlet conditions are considered. These ones are satisfied imposing:

$$\hat{T}(x) = \Psi(x) + \sum_{j=1}^{M} T_j \cdot \Phi_j\,(x) \qquad (2.37)$$

Where $\Psi(x)$ is any equation that satisfies the boundary conditions and Φ_j nullify themselves in correspondence of the edge.

Introducing this one in the weighted residues integral it is possible to obtain an equation system that can be written as:

$$K \cdot T = c \qquad (2.38)$$

Where:

- K is the global stiffness matrix,;
- T is the coefficient vector;
- c is the load vector.

Inverting this equation it is possible to calculate the final coefficients T_j.

2.5.3 FVM and FEM according to the UNI EN ISO 10211

The Finite Volume Method (FVM) and the Finite Element Method (FEM) are defined by the UNI EN ISO 10211 [N5] as numerical methods with an high precision calculation, which require a subdivision of the object considered. "The method is a set of rules to form a system of equations, the number of which is proportional to the number of subdivisions. The system is solved using either a direct solution method or an iterative method. The solution of the system is normally the temperatures at specific points, from which the temperatures at any point of the object considered can be derived (by interpolation); the heat flows through specific surfaces can also be derived."

The UNI EN ISO 10211 [N5] imposes that:

- "the method shall provide temperatures and heat flows;
- the extent of subdivision of the object (i.e. the number of cells, nodes) is not "method defined" but "user defined", although in practice the degree of subdivision is "machine limited". Therefore, in the test reference cases, the method being validated shall be able to calculate temperatures and heat flows at locations other than those listed;
- for an increasing number of subdivisions, the solution of the method being validated shall converge to the analytical solution, if such a solution exists;
- the number of subdivisions shall be determined as follows: the sum of the absolute values of all the heat flows entering the object is calculated twice, for n nodes (or cells) and for 2n nodes (or cells). The difference between these two results shall not exceed 1%. If not, further subdivisions shall be made until this criterion is met;
- if the system solution technique is iterative, the iteration shall continue until the sum of all heat flows (positive and negative) entering the object, divided by half the sum of the absolute values of all these heat flows, is less than 0,0001."

The norm adds as note that: "for an increasing number of subdivisions, the solution converges. The number of subdivisions required to obtain good accuracy depends on the problem considered and on the solution technique. The error is expected to take the form $\alpha/N^{\beta/3}$ where α and β are constants for a given problem and N is the total number of nodes in the model."

2.5.4 FLUENT

The program used in this study to simulate every type of thermal bridge is FLUENT 6.3.26, which uses finite volume simulations.

"FLUENT is a state-of-the-art computer program for modeling fluid flow and heat transfer in complex geometries. It provides complete mesh flexibility, including the ability to solve your flow problems using unstructured meshes that can be generated about complex geometries with relative ease" [B5].

"It is written in the C computer language and makes full use of the flexibility and power offered by the language. Consequently, true dynamic memory allocation, efficient data structures, and flexible solver control are all possible" [B5].

"FLUENT package includes the following products:

- FLUENT, which is the solver;
- GAMBIT, which is the preprocessor for geometry modeling and mesh generation;
- TGrid, which is an additional preprocessor that can generate volume meshes from existing boundary meshes;
- Filters (translators) for import of surface and volume meshes from CAD/CAE packages such as ANSYS, CGNS, I-deas, NASTRAN, PATRAN, and others."[B5]

The program structure is the following one:

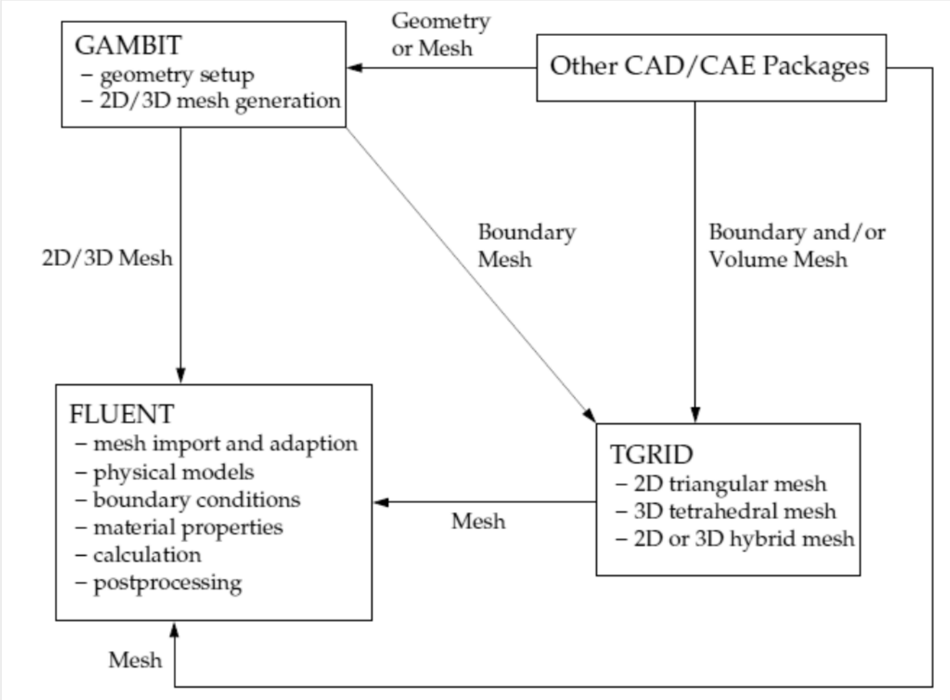


Figure 2.18 - Basic program structure [B4]

Ones the mesh is created by GAMBIT, "all remaining operations are performed within FLUENT. These include setting boundary conditions, defining fluid properties, executing the solution, refining the mesh, and viewing and postprocessing the results." [B5]

"The FLUENT solver has the following modeling capabilities:

- 2D planar, 2D axisymmetric, 2D axisymmetric with swirl (rotationally symmetric), and 3D flows;
- Quadrilateral, triangular, hexahedral (brick), tetrahedral, prism (wedge), pyramid, polyhedral and mixed element meshes;
- Steady-state or transient flows
- Incompressible or compressible flows, including all speed regimes (low subsonic, transonic, supersonic and hypersonic flows);
- Inviscid, laminar, and turbulent flows;
- Newtonian or non-Newtonian flows;
- Heat transfer, including forced, natural, and mixed convection, conjugate (solid/fluid) heat transfer, and radiation;
- Chemical species mixing and reaction, including homogeneous and heterogeneous combustion models and surface deposition/reaction models;
- Free surface and multiphase models for gas-liquid, gas-solid, and liquid-solid flows;
- Lagrangian trajectory calculation for dispersed phase (particles/droplets/bubbles), including coupling with continuous phase and spray modeling;
- Cavitation model;
- Phase change model for melting/solidification applications;
- Porous media with non-isotropic permeability, inertial resistance, solid heat conduction, and porous-face pressure jump conditions;
- Lumped parameter models for fans, pumps, radiators, and heat exchangers;
- Acoustic models for predicting flow-induced noise;
- Inertial (stationary) or non-inertial (rotating or accelerating) reference frames;
- Multiple reference frame (MRF) and sliding mesh options for modeling multiple moving frames;
- Mixing-plane model for modeling rotor-stator interactions, torque converters, and similar turbomachinery applications with options for mass conservation and swirl conservation;
- Dynamic mesh model for modeling domains with moving and deforming mesh;
- Volumetric sources of mass, momentum, heat, and chemical species;
- Material property database;
- Extensive customization capability via user-defined functions;
- Dynamic (two-way) coupling with GT-Power and WAVE;
- Magnetohydrodynamics (MHD) module (documented separately);
- Continuous fiber module (documented separately);
- Fuel cell modules (documented separately);
- Population balance module (documented separately).

FLUENT is ideally suited for incompressible and compressible fluid-flow simulations in complex geometries" [B5].

The software used in this case of study to model every simulation and to create the mesh is GAMBIT, which is "a software package designed to help analysts and designers to build and mesh models for computational fluid dynamics (CFD) and other scientific application" [W6].

2.5.5 THERM

The program used to do the simulation necessary to validate the reference abacus is THERM 5.2.

"THERM is a state-of-the-art, Microsoft Windows-based computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.

THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products. The program's graphic interface allows you to draw cross sections of products or components to be analyzed. To create the cross sections, you can trace imported files in DXF or bitmap format, or input the geometry from known dimensions. Each cross section is represented by a combination of polygons. You define the material properties for each polygon and introduce the environmental conditions to which the component is exposed by defining the boundary conditions surrounding the cross section. Once the model is created, the remaining analysis (mesher and heat transfer) is automatic. You can view results from THERM in several forms, including U-factors, isotherms, heat-flux vectors, and local temperatures."

"THERM is a module of the WINDOW+5 program under development by LBNL. WINDOW+5 is the next generation of the WINDOW software series and is being developed for the Microsoft Windows operating environment. THERM's results can be used with WINDOW's center-of-glass optical and thermal models to determine total window product U-factors and Solar Heat Gain Coefficients."

"THERM has three basic components:

- ☐a graphic user interface that allows you to draw a cross section of the product or component for which you are performing thermal calculations.
- ☐a heat-transfer analysis component that includes: an automatic mesh generator to create the elements for the finite-element analysis, a finite-element solver, an optional error estimator and adaptive mesh generator, and an optional view-factor radiation model.
- ☐a results displayer."

"The results from THERM's finite-element analysis of a fenestration product or building component can be viewed as:

- ☐U-factors;
- ☐isotherms;
- ☐color-flooded isotherms;
- ☐heat-flux vector plots;
- ☐color-flooded lines of constant flux;
- ☐temperatures (local and average, maximum and minimum)." [B6]

2.6 STATISTICAL PRINCIPLES

The linear thermal transmittance has been calculated through simulations for each thermal bridge configuration, characterized by different thicknesses of brick and insulation and by different brick densities. These final values have been unified in some correlations, one for each type of thermal bridge.

A correlation indicates the relation degree among some variables: these variables are perfectly correlated when everyone satisfies an equation (e.g. circumference and radius), whereas they are uncorrelated, when none satisfies it. If every point of a scatter diagram seams to lay on a straight line, there's a linear correlation. When Y grows with X growth, the correlation is called positive, whereas when Y decreases with X growth the correlation is called negative.

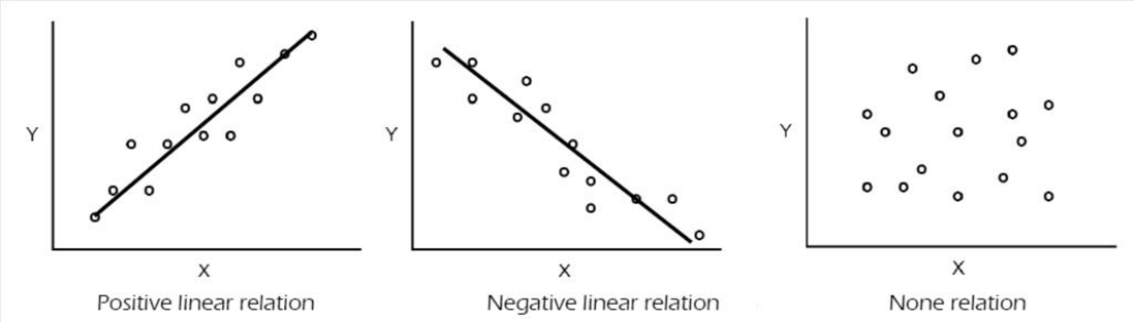


Figure 2.19 - Correlation examples [W5]

A curve correlation is a non-linear correlation and it can be positive and negative at the same time.

When a scatter diagram is described by a linear equation it is important to evaluate how it is able to represent this variables relation. One of the most important parameter to analyze it is the correct valuation standard error, which is (for small samples as in the case of study):

$$\hat{s}_{Y,X} = \sqrt{\frac{N}{N-2}} \cdot s_{Y,X} = \sqrt{\frac{\sum_{i=1}^{N}\left(Y_i - Y_{est,i}\right)^2}{N-2}} \qquad (2.39)$$

Where:

- $\hat{s}_{Y,X}$ is the correct valuation standard error;
- $s_{Y,X}$ is the valuation standard error;
- N is the number of the points calculated through the simulations and used for the determination of the final correlations;
- Y_i is the value determined through simulation, for the i^{th} couple of parameters;
- $Y_{est,I}$ is the value determined through correlation, for the i^{th} couple of parameters.

The valuation standard error has properties similar to standard deviation: if there were straight lines parallel to the correlation one with a distance equal to $s_{Y,X}$, $2*s_{Y,X}$ and $3*s_{Y,X}$ a lot of values would be inside them: respectively 68%, 95% and 99,7%.

In fact the valuation standard error is introduced in every report of this study through an indication of the confidence interval, which is the interval in which it is possible to find the real solution with a probability of 95%:

$$IC^{95\%} = 2 \cdot \hat{s}_{x,y} \tag{2.40}$$

It's important to point out that this value is calculated for each schematization of this analysis. If the correlations are used for other technological junction between building elements, whose schematization doesn't correspond with the ones indicated in the report, the probability to find the real solution inside the confidence interval could be less than 95%.

Another important parameter to evaluate the precision of a linear correlation is the correlation coefficient, which allows to assess the difference between the real values and the estimated ones. Its definition starts from the total deviance, which is:

$$\sum_{i=1}^{N}(Y_i - \bar{Y})^2 = \sum_{i=1}^{N}\left(Y_i - Y_{est,i}\right)^2 + \sum_{i=1}^{N}\left(Y_{est,i} - \bar{Y}\right)^2 \tag{2.41}$$

Where $\bar{Y}$ is the Y_i average.

The first term of the right member of the equation corresponds to the residual deviance, the second one is the explained deviance. The correlation coefficient is the square root of the ratio between the explained deviance and the total one:

$$r = \pm\sqrt{\frac{\sum_{i=1}^{N}\left(Y_{est,i} - \bar{Y}\right)^2}{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}} = \pm\sqrt{1 - \frac{s_{Y,X}^2}{s_Y^2}} \tag{2.42}$$

Where s_Y is the standard deviation of Y:

$$s_Y = \sqrt{\frac{\sum_{i=1}^{N}(Y_i - \bar{Y})^2}{N}} \tag{2.43}$$

If the explained deviance is null, this coefficient is null: this means that the estimated value is the same of the average and so there isn't a linear correlation; whereas if the residual deviance is null, r is equal to 1 or -1 (respectively for positive and negative correlations): this means that the real values and the estimated ones are the same and so there's a perfect correlation.

r is non-dimensional and so it doesn't depend on the unit of measurement and also it doesn't depend on the type of correlation used, but only on the obtained results. In fact if r is null with values determined through a linear correlation, it means that the this type of correlation isn't possible, but there could be a non-linear one.

What has been said so far is referred to relation between two variables, but for example in case of three variables (multiple correlation), the rules indicated before for valuation standard error ***(2.39)*** and correlation coefficient ***(2.42)*** become:

$$\hat{s}_{Y,XZ} = \sqrt{\frac{N}{N-3}} \cdot s_{Y,XZ} = \sqrt{\frac{\sum_{i=1}^{N}\left(Y_i - Y_{est,i}\right)^2}{N-3}} \tag{2.44}$$

$$R_{Y,XZ} = \sqrt{1 - \frac{s_{Y,XZ}^2}{s_Y^2}} \qquad (2.45)$$

Where:

- $\hat{s}_{Y,XZ}$ is the correct valuation standard error;
- $s_{Y,XZ}$ is the valuation standard error;
- N is the number of the points calculated through the simulations and used for the determination of the final correlations;
- Y_i is the value determined through simulation, for the ith group of parameters;
- $Y_{est,i}$ is the value determined through correlation, for the ith group of parameters;
- $R_{Y,XZ}$ is the multiple correlation coefficient;
- s_Y is the standard deviation of Y.

For the validation it has been used also the mean square error (MSE), which is better explained in chapter **4.1**.

3 THERMAL BRIDGES ABACUS COMPOSITION

3.1 LINEAR THERMAL TRANSMITTANCE CALCULATION

The UNI EN ISO 10211 [N5] defines the linear thermal transmittance as the "heat flow rate in the steady state divided by length and by the temperature difference between the environments on either side of a thermal bridge":

$$\Psi = \frac{\phi^{2D} - \sum_i^N \phi_i^{1D}}{L_{TB} \cdot \Delta T} \quad (\frac{W}{m \cdot K}) \qquad (3.1)$$

Where:

- Φ^{2D} is the heat flow rate determined through a two-dimensional calculation;
- Φ^{1D} is the heat flow rate determined through a one-dimensional calculation;
- L_{TB} is the characteristic length of the thermal bridge;
- ΔT is the difference between internal and external air temperatures.

So the linear thermal transmittance allows the calculation of the additional heat flow rate due to the thermal bridge compared with the one-dimensional heat flow rate obtained for the building elements composing the junction. Operatively it can be determined in the following way:

$$\Psi = \frac{\phi^{2D} - \sum_i^N \phi_i^{1D}}{L_{TB} \cdot \Delta T} = \frac{\phi^{2D}}{L_{TB} \cdot \Delta T} - \sum_i^N \frac{\phi_i^{1D}}{L_{TB} \cdot \Delta T} = L_{2D} - \sum_i^N U_i \cdot l_i \quad (\frac{W}{m \cdot K}) \qquad (3.2)$$

Where:

- L_{2D} is the thermal coupling coefficient determined through a two-dimensional calculation;
- U_i is the thermal transmittance of the ith building element;
- l_i is the length of the ith building element in the geometric model considered (it is different in the hypothesis of calculation based on internal or external dimensions).

The thermal transmittance of each building element is determined according to the UNI EN ISO 6946 [N1].

The UNI EN ISO 10211 [N5] defines the thermal coupling coefficient as the "heat flow rate per temperature difference between two environments which are thermally connected by the construction under consideration."

The simulations done through the calculation code provide the two-dimensional heat flow rate Φ^{2D} and so it has been possible to determine the thermal coupling coefficient in the following way with an hypothesis of L_{TB}=1m:

$$L_{2D} = \frac{\phi^{2D}}{L_{TB} \cdot (T_i - T_e)} \quad (\frac{W}{m \cdot K}) \qquad (3.3)$$

In the linear thermal transmittance calculation it is important to point out which dimensions the calculation is based on (internal Ψ_I or external Ψ_E). For a lot of types of thermal bridge this differentiation is fundamental.

As said before, the values obtained from all the simulations for a type of thermal bridge are unified, using MATLAB, in a correlation in function of some parameters, which defines thermophysical and geometrical characteristics of the thermal bridge itself.

3.2 TEMPERATURE FACTOR AT THE INTERNAL SURFACE DETERMINATION

As said before, the UNI EN ISO 13788 [N7] defines the temperature factor at the internal surface as "the difference between the temperature of the internal surface and the external air temperature, divided by the difference between the internal air temperature and the external air temperature, calculated with a surface resistance at the internal surface R_{si}":

$$f_{Rsi} = \frac{T_{si} - T_e}{T_i - T_e} \quad (-)$$

In order to create a reference abacus it has been referred to the minimum acceptable value:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} \quad (-)$$

To obtain this value for each schematization of thermal bridge, at the beginning, it has been necessary to extrapolate T_{si} values for each simulation (differenced for brick and insulation thickness and for brick densities) and then to consider the smallest one, which is in correspondence of the discontinuity element. So, applying the temperature factor at the internal surface definition with the design hypothesis of T_i=20°C and T_e=-5°C, it has been possible to determine its minimum acceptable value.

Finally, using MATLAB, these are unified in some correlation (one for each schematization of thermal bridge) in function of some parameters, which define thermally the schematization itself.

The criteria with which one correlation has been chosen among the other are:

- the confidence interval amplitude;
- the use of parameters simple to obtain;
- to try to have the same parameters to define the correlation of junctions with similar constructive characteristics, such the un-insulated pillar or the insulated roof.

The cases of junction between external wall and pillar totally insulated outside or inside (PIL.007 and PIL.008 reports) are particular because the simulations about them determine a linear thermal transmittance values very similar to zero. This means that the thermal bridge influence is negligible, the isotherms are parallel and so the temperatures at the internal surface due to the wall and the pillar are very similar. To allow a greater margin of security, it has been taken into consideration the temperature in correspondence of the pillar.

Using one-dimensional laws, it is possible to obtain:

$$T_{si,min} = T_i - \frac{U_P}{h_i} \cdot (T_i - T_e) \quad (°C)$$

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} \quad (-)$$

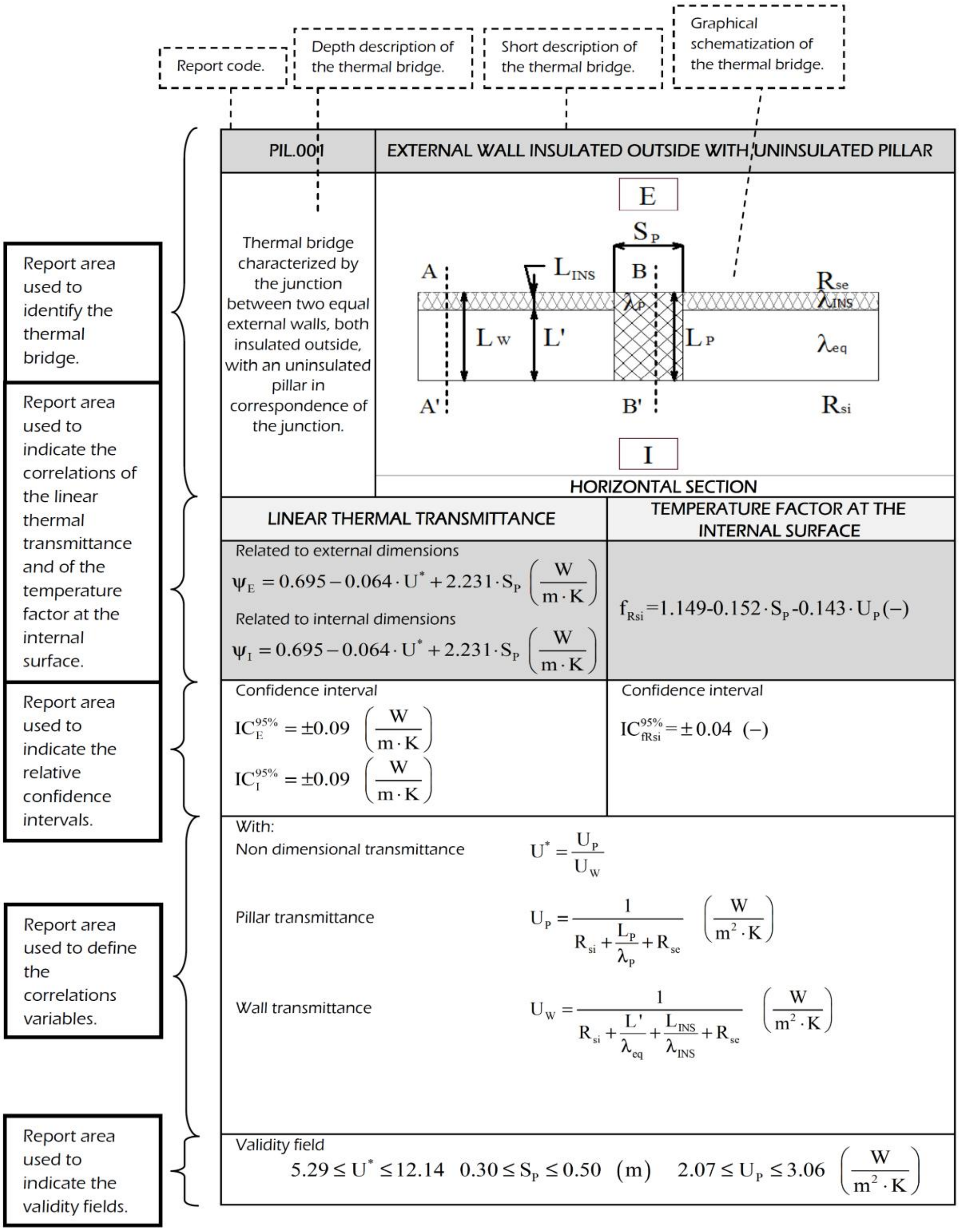
$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} = \frac{1}{T_i - T_e} \cdot \left[T_i - \frac{U_P}{h_i} \cdot (T_i - T_e) - T_e \right] = 1 - \frac{U_P}{h_i} = 1 - R_{si} \cdot U_P \quad (-)$$

The reports shown in the following pages aren't all of the CESTEC-ANCE thermal bridges abacus: in default of the simulations on ridges and compluviums it hasn't been possible to evaluate the values of surface temperature for these cases. There are no simulations on them because the equations provided by the reference abacus had been developed with a geometrical approach.

3.3 THERMAL BRIDGES ABACUS REPORTS

3.3.1 Reports structure

The **Figure 3.1** shows the structure of the reports that compose the thermal bridges abacus.



PIL.001	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the junction between two equal external walls, both insulated outside, with an uninsulated pillar in correspondence of the junction.	HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \left(\frac{W}{m \cdot K}\right)$	f_{Rsi}=1.149-0.152$\cdot S_P$-0.143$\cdot U_P(-)$
Confidence interval $IC_E^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

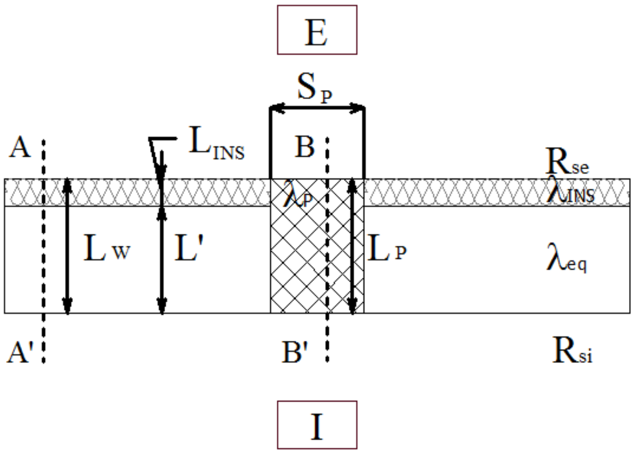
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14 \quad 0.30 \le S_P \le 0.50 \ (m) \quad 2.07 \le U_P \le 3.06 \left(\frac{W}{m^2 \cdot K}\right)$

Figure 3.1 - Structure of the reports of the thermal bridges abacus

3.3.2 Junction between external wall and un-insulated pillar

PIL.001	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the junction between two equal external walls, both insulated outside, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \ \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \ \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.149 - 0.152 \cdot S_P - 0.143 \cdot U_P (-)$
Confidence interval $IC_E^{95\%} = \pm 0.09 \ \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \ \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$

With:

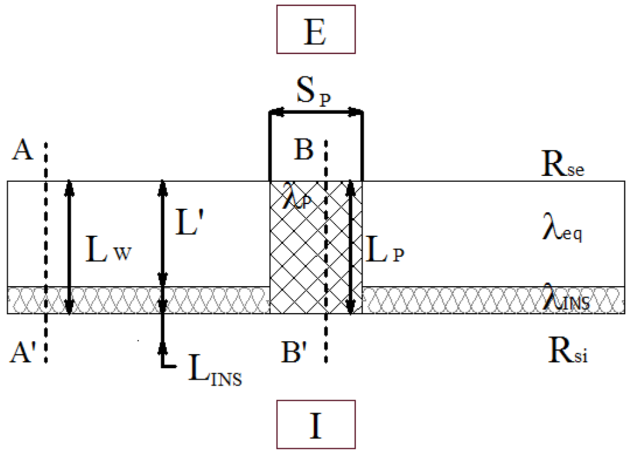
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \ \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \ \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$5.29 \le U^* \le 12.14 \quad 0.30 \le S_P \le 0.50 \ (m) \quad 2.07 \le U_P \le 3.06 \ \left(\frac{W}{m^2 \cdot K}\right)$$

PIL.002	EXTERNAL WALL INSULATED INSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the junction between two equal external walls, both insulated inside, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.455 - 0.047 \cdot U^* + 2.179 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.455 - 0.047 \cdot U^* + 2.179 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$	f_{Rsi}=0.933+0.051$\cdot S_P$-0.123$\cdot U_P (-)$
Confidence interval $IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.04 \quad (-)$

With:

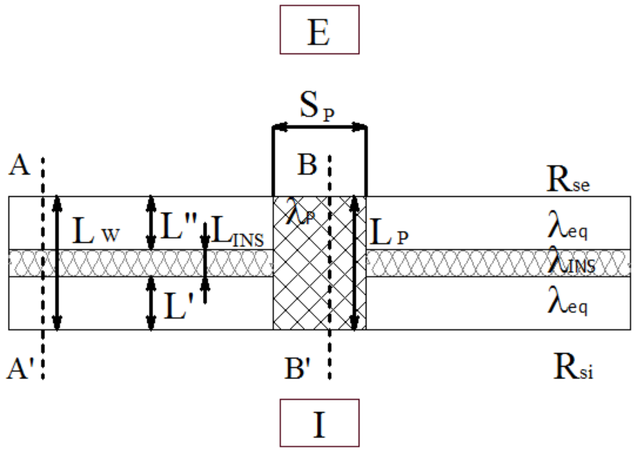
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L'}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$5.29 \le U^* \le 12.14 \quad 0.30 \le S_P \le 0.50 \quad (m) \quad 2.07 \le U_P \le 3.06 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

PIL.003	EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED PILLAR
Thermal bridge characterized by the junction between two equal external walls, both insulated in the middle, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.650 - 0.060 \cdot U^* + 2.176 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.650 - 0.060 \cdot U^* + 2.176 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.114 - 0.117 \cdot S_P - 0.143 \cdot U_P (-)$
Confidence interval $IC_E^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance

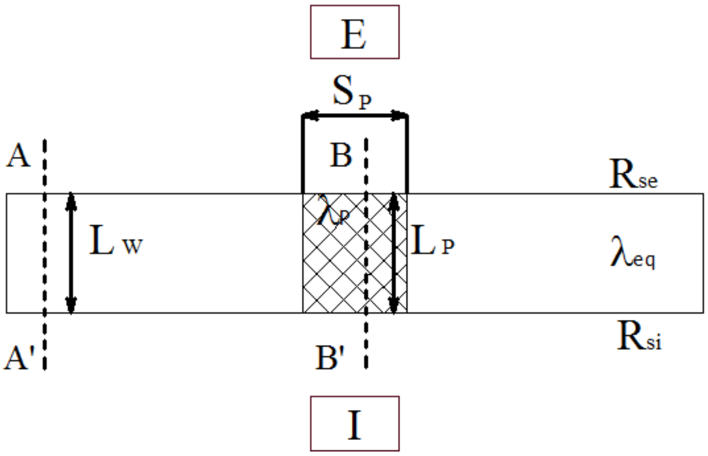
$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

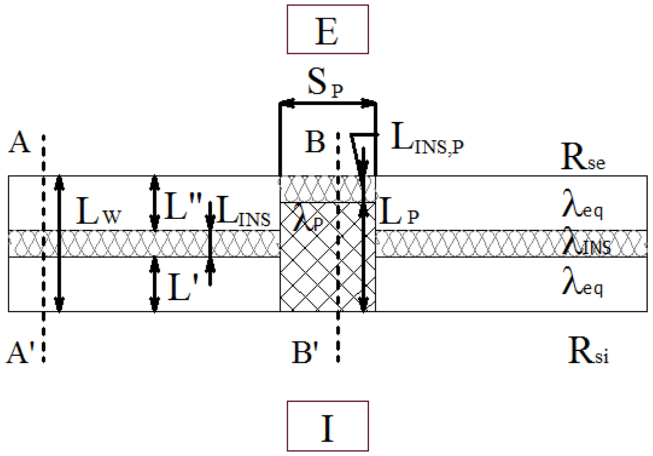
Validity field

$$5.29 \le U^* \le 12.14 \quad 0.30 \le S_P \le 0.50 \quad (m) \quad 2.07 \le U_P \le 3.06 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

<table>
<tr><th>PIL.004</th><th colspan="2">UNINSULATED EXTERNAL WALL WITH UNINSULATED PILLAR</th></tr>
<tr><td>Thermal bridge characterized by the junction between two equal external walls, both uninsulated, with an uninsulated pillar in correspondence of the junction.</td><td colspan="2">

HORIZONTAL SECTION</td></tr>
<tr><th colspan="2">LINEAR THERMAL TRANSMITTANCE</th><th>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</th></tr>
<tr><td colspan="2">Related to external dimensions
$$\psi_E = 0.436 - 0.769 \cdot \lambda_{eq} + 1.656 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$$
Related to internal dimensions
$$\psi_I = 0.436 - 0.769 \cdot \lambda_{eq} + 1.656 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$$</td><td>$$f_{Rsi} = 1.070 - 0.070 \cdot S_P - 0.138 \cdot U_P \, (-)$$</td></tr>
<tr><td colspan="2">Confidence interval
$$IC_E^{95\%} = \pm 0.16 \quad \left(\frac{W}{m \cdot K}\right)$$
$$IC_I^{95\%} = \pm 0.16 \quad \left(\frac{W}{m \cdot K}\right)$$</td><td>Confidence interval
$$IC_{fRsi}^{95\%} = \pm 0.003 \quad (-)$$</td></tr>
<tr><td colspan="3">With:</td></tr>
<tr><td colspan="3">Validity field
$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.30 \le S_P \le 0.50 \ (m) \qquad 2.47 \le U_P \le 3.32 \left(\frac{W}{m^2 \cdot K}\right)$$</td></tr>
</table>

3.3.3 Junction between external wall and insulated pillar

PIL.005	EXTERNAL WALL INSULATED IN THE MIDDLE WITH PILLAR INSULATED OUTSIDE
Thermal bridge characterized by the junction between two equal external walls, both insulated in the middle, with a pillar insulated outside in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.006 + 0.088 \cdot U^* + 0.528 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.006 + 0.088 \cdot U^* + 0.528 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.960 - 0.143 \cdot U_P - 0.074 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.03 \; (-)$

With:

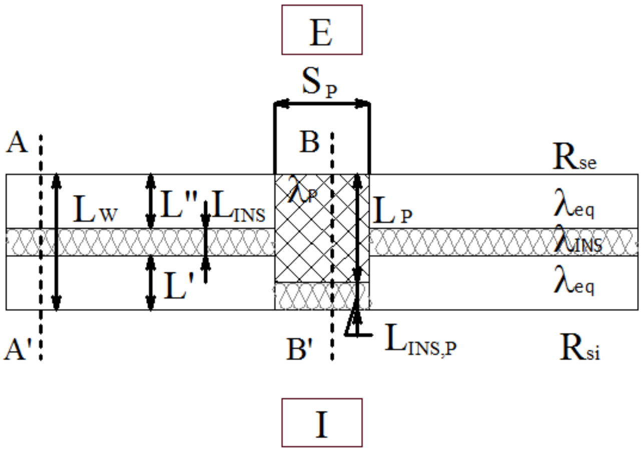
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$1.08 \le U^* \le 3.44$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.24 \le U_P \le 0.65 \left(\frac{W}{m^2 \cdot K}\right)$

PIL.006	EXTERNAL WALL INSULATED IN THE MIDDLE WITH PILLAR INSULATED INSIDE
Thermal bridge characterized by the junction between two equal external walls, both insulated in the middle, with a pillar insulated inside in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.001 + 0.093 \cdot U^* + 0.510 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.001 + 0.093 \cdot U^* + 0.510 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.014 - 0.247 \cdot U_P - 0.126 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance

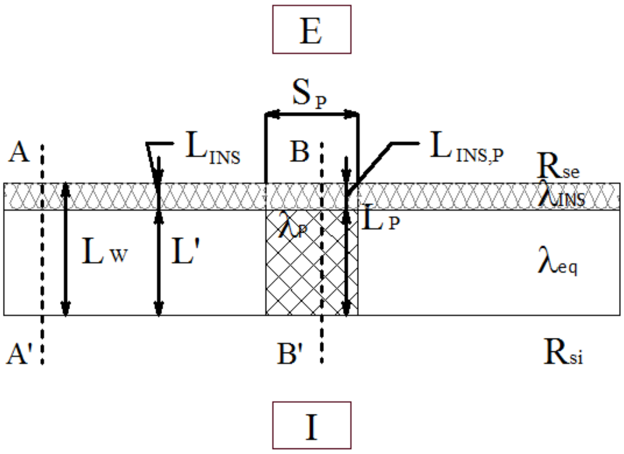
$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

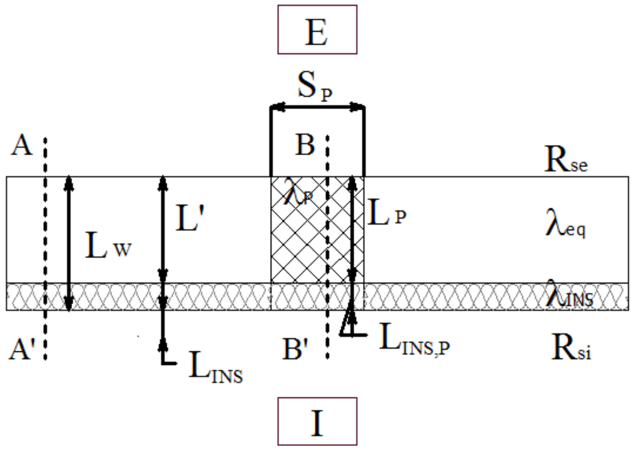
Validity field

$1.08 \le U^* \le 3.44$ $0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $0.24 \le U_P \le 0.65 \left(\frac{W}{m^2 \cdot K}\right)$

<table>
<tr><th>PIL.007</th><th colspan="2">EXTERNAL WALL INSULATED OUTSIDE WITH PILLAR INSULATED OUTSIDE</th></tr>
<tr><td>Thermal bridge characterized by the junction between two equal external walls, both insulated outside, with a pillar insulated outside in correspondence of the junction.</td><td colspan="2">
HORIZONTAL SECTION</td></tr>
<tr><td colspan="2">LINEAR THERMAL TRANSMITTANCE</td><td>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</td></tr>
<tr><td colspan="2">Related to external dimensions
$\psi_E = 0 \quad \left(\frac{W}{m \cdot K}\right)$
Related to internal dimensions
$\psi_I = 0 \quad \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = 1 - R_{si} \cdot U_P (-)$</td></tr>
<tr><td colspan="2">Confidence interval</td><td>Confidence interval</td></tr>
<tr><td colspan="3">With:
Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field
$0.24 \le U_P \le 0.65 \quad \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
</table>

PIL.008	EXTERNAL WALL INSULATED INSIDE WITH PILLAR INSULATED INSIDE

Thermal bridge characterized by the junction between two equal external walls, both insulated inside, with a pillar insulated inside in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0 \left(\frac{W}{m\cdot K}\right)$ Related to internal dimensions $\psi_I = 0 \left(\frac{W}{m\cdot K}\right)$	$f_{Rsi}=1-R_{si}\cdot U_P(-)$
Confidence interval	Confidence interval

With:

Pillar transmittance

$$U_P = \frac{1}{R_{si}+\frac{L_P}{\lambda_P}+\frac{L_{INS,P}}{\lambda_{INS}}+R_{se}} \left(\frac{W}{m^2\cdot K}\right)$$

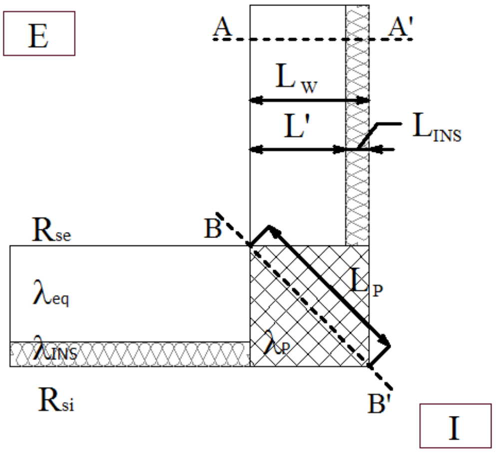
Validity field

$$0.24 \le U_P \le 0.65 \left(\frac{W}{m^2\cdot K}\right)$$

3.3.4 Concave corner with un-insulated pillar

CC.001	CONCAVE CORNER INSULATED INSIDE WITH UNINSULATED PILLAR

Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated inside, with an uninsulated pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.064 + 0.033 \cdot U^* + 0.975 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.326 + 0.055 \cdot U^* + 0.924 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi}=0.977-0.263 \cdot U_W-0.118 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%}=\pm 0.01 \quad (-)$

With:

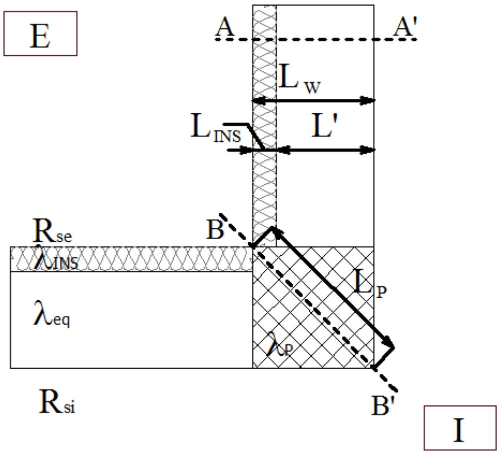
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

CC.002	CONCAVE CORNER INSULATED OUTSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated outside, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.095 + 0.006 \cdot U^* - 0.017 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.296 + 0.027 \cdot U^* - 0.068 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.991 - 0.124 \cdot U_W + 0.011 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.004 \quad (-)$

With:

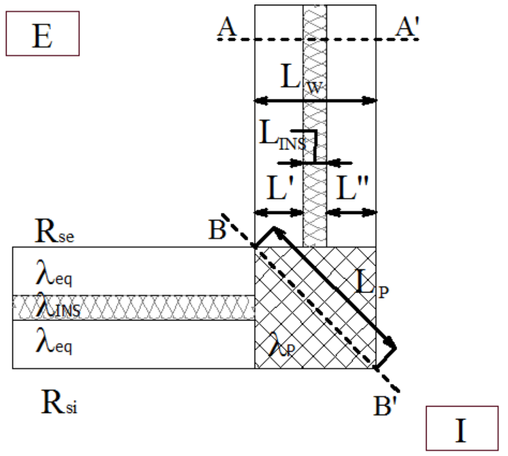
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

CC.003	CONCAVE CORNER INSULATED IN THE MIDDLE WITH UNINSULATED PILLAR
Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated in the middle, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.175 + 0.021 \cdot U^* + 0.703 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.216 + 0.042 \cdot U^* + 0.652 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.964 - 0.181 \cdot U_W - 0.033 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.004 \; (/)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance
$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

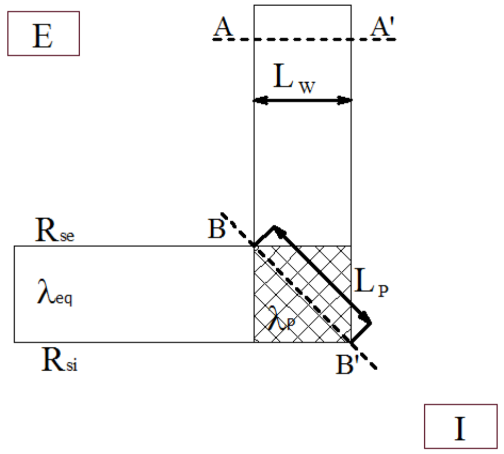
Wall transmittance
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

CC.004 — UNINSULATED CONCAVE CORNER WITH UNINSULATED PILLAR

Thermal bridge characterized by the concave squarely junction between two equal external walls, both uninsulated, with an uninsulated pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.515 - 0.047 \cdot U^* + 0.223 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.240 - 0.019 \cdot U^* - 0.936 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.07 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 1.018 - 0.130 \cdot U_W - 0.012 \cdot \frac{1}{\lambda_{eq}} \; (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \; (-)$$

With:

Non dimensional transmittance $U^* = \dfrac{U_P}{U_W}$

Pillar transmittance $U_P = \dfrac{1}{R_{si} + \dfrac{L_P}{\lambda_P} + R_{se}} \quad \left(\dfrac{W}{m^2 \cdot K}\right)$

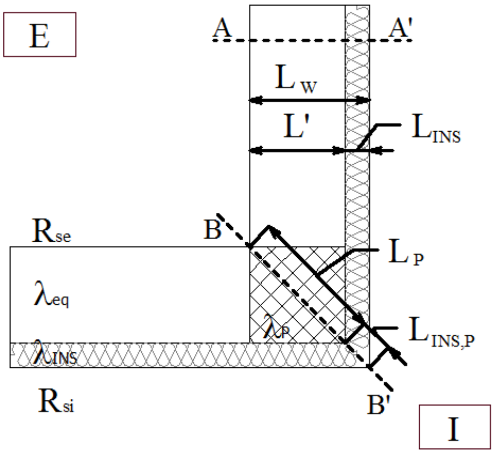
Wall transmittance $U_W = \dfrac{1}{R_{si} + \dfrac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\dfrac{W}{m^2 \cdot K}\right)$

Validity field

$$1.52 \le U^* \le 4.59 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.47 \le U_W \le 2.09 \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.5 Concave corner with insulated pillar

<table>
<tr><th>CC.005</th><th>CONCAVE CORNER INSULATED INSIDE WITH PILLAR INSULATED INSIDE</th></tr>
<tr><td>Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated inside, with a pillar insulated inside in correspondence of the junction.</td><td>



HORIZONTAL SECTION</td></tr>
</table>

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.052 + 0.389 \cdot U^* - 0.043 \cdot \frac{1}{\lambda_{eq}} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.076 + 0.046 \cdot U^* - 0.020 \cdot \frac{1}{\lambda_{eq}} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.980 + 0.025 \cdot L_P - 0.109 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

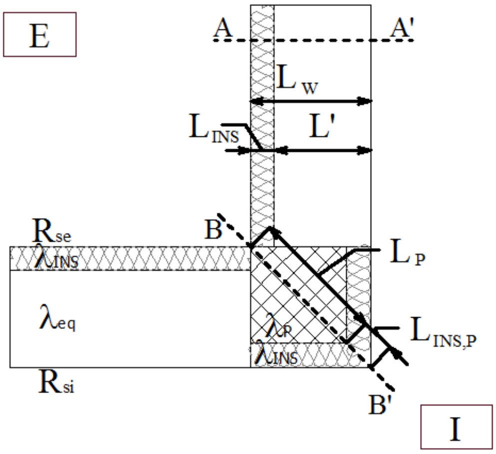
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$0.76 \le U^* \le 1.18 \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.14 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 0.35 \le L_P \le 0.64 (m)$

CC.006 — CONCAVE CORNER INSULATED OUTSIDE WITH PILLAR INSULATED INSIDE

Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated outside, with a pillar insulated inside in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.078 + 0.015 \cdot U^* - 0.019 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = -0.163 + 0.044 \cdot U^* - 0.140 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.10 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 1.005 - 0.022 \cdot L_P - 0.135 \cdot U_W (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance

$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

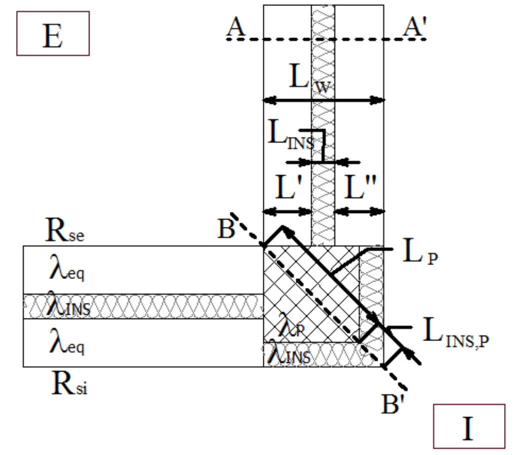
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.31 \le U^* \le 2.51 \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 0.35 \le L_P \le 0.64 (m)$$

CC.007 — CONCAVE CORNER INSULATED IN THE MIDDLE WITH PILLAR INSULATED INSIDE

Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated in the middle, with a pillar insulated inside in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.104 + 0.055 \cdot U^* + 0.502 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = -0.117 + 0.074 \cdot U^* + 0.377 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.12 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.14 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 1.279 - 0.412 \cdot L_P - 0.582 \cdot U_W (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

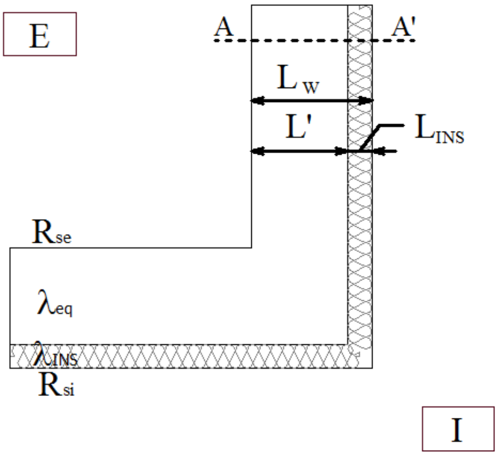
Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$0.77 \le U^* \le 2.51 \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 0.35 \le L_P \le 0.64 (m)$$

3.3.6 Concave corner without pillar

CC.008	CONCAVE CORNER INSULATED INSIDE WITHOUT PILLAR
Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated inside, without pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.070 + 0.254 \cdot U_W - 0.085 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.222 + 0.683 \cdot U_W - 0.202 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.000\text{-}0.130 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.00 \quad (-)$

With:

Wall transmittance

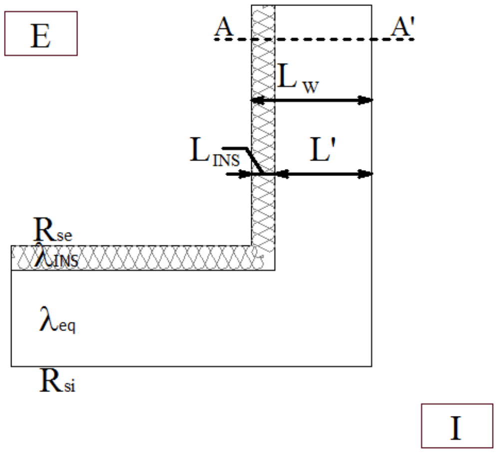
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

CC.009	CONCAVE CORNER INSULATED OUTSIDE WITHOUT PILLAR

Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated outside, without pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.043 + 0.129 \cdot U_W + 0.132 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.094 - 0.121 \cdot U_W + 0.038 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.002 - 0.133 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.001 \quad (-)$

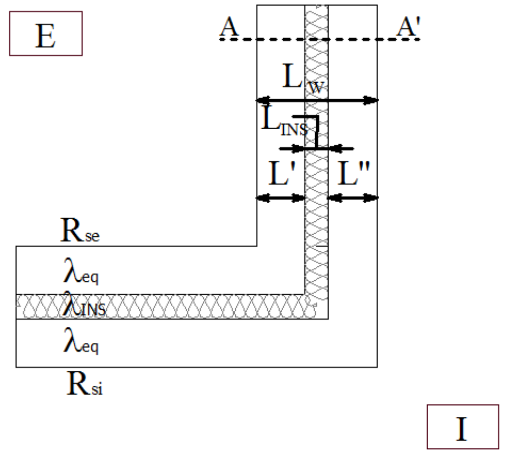
With:

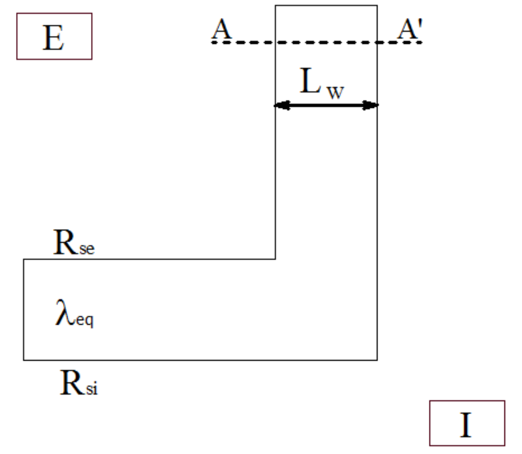
Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \leq \lambda_{eq} \leq 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \leq U_W \leq 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

CC.010	CONCAVE CORNER INSULATED IN THE MIDDLE WITHOUT PILLAR
Thermal bridge characterized by the concave squarely junction between two equal external walls, both insulated in the middle, without pillar in correspondence of the junction.	 HORIZONTAL SECTION
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.110 + 0.078 \cdot U_W - 0.013 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.157 - 0.104 \cdot U_W - 0.010 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.000 - 0.131 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.00 \quad (-)$
With: Wall transmittance	$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$
Validity field	$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$

CC.011	UNINSULATED CONCAVE CORNER WITHOUT PILLAR
Thermal bridge characterized by the concave squarely junction between two equal external walls, both uninsulated, without pillar in correspondence of the junction.	

HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.238 - 0.061 \cdot U_W + 0.260 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.004 + 0.365 \cdot U_W - 2.163 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.985 - 0.128 \cdot U_W + 0.017 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.19 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

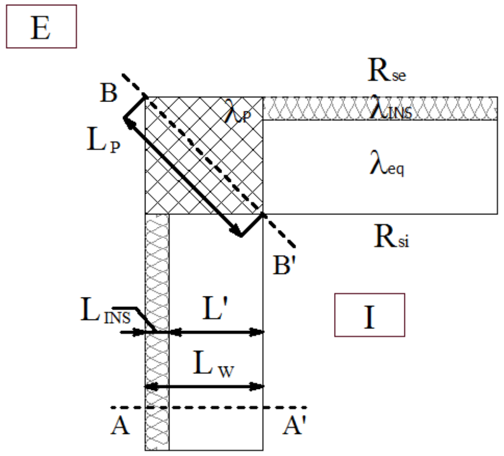
Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \leq \lambda_{eq} \leq 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.47 \leq U_W \leq 2.09 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.7 Projecting corner with un-insulated pillar

PC.001	PROJECTING CORNER INSULATED OUTSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated outside, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.408 + 0.058 \cdot U^* + 0.944 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.018 + 0.036 \cdot U^* + 0.996 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.632 - 0.246 \cdot U_W + 0.128 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance

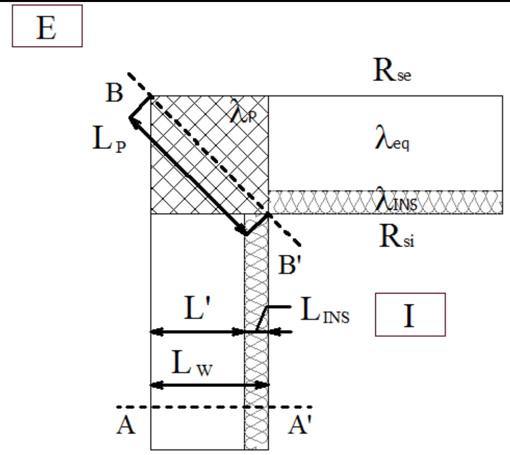
$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

PC.002	PROJECTING CORNER INSULATED INSIDE WITH UNINSULATED PILLAR
Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated inside, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.319 + 0.028 \cdot U^* - 0.068 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.071 + 0.007 \cdot U^* - 0.017 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.738 - 0.034 \cdot U_W \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.002 \quad (-)$

With:

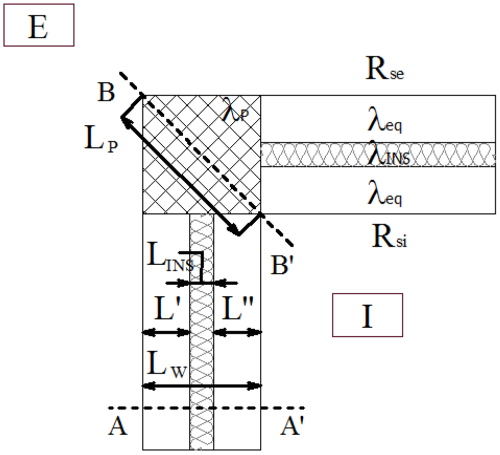
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$

PC.003	PROJECTING CORNER INSULATED IN THE MIDDLE WITH UNINSULATED PILLAR
Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated in the middle, with an uninsulated pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.310 + 0.047 \cdot U^* + 0.612 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.080 + 0.026 \cdot U^* + 0.664 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.628 - 0.252 \cdot U_W + 0.117 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

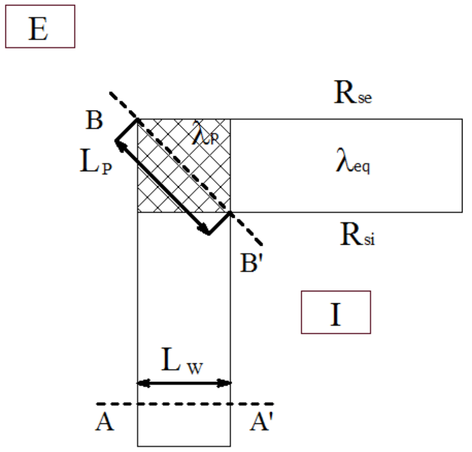
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$4.41 \le U^* \le 10.94 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$

PC.004	UNINSULATED PROJECTING CORNER WITH UNINSULATED PILLAR

Thermal bridge characterized by the projecting squarely junction between two equal external walls, both uninsulated, with an uninsulated pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.075 + 0.025 \cdot U^* - 1.056 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.350 - 0.003 \cdot U^* + 0.103 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.19 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.09 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.592 - 0.125 \cdot U_W + 0.194 \cdot \lambda_{eq} \; (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \; (-)$$

With:

Non dimensional transmittance $U^* = \dfrac{U_P}{U_W}$

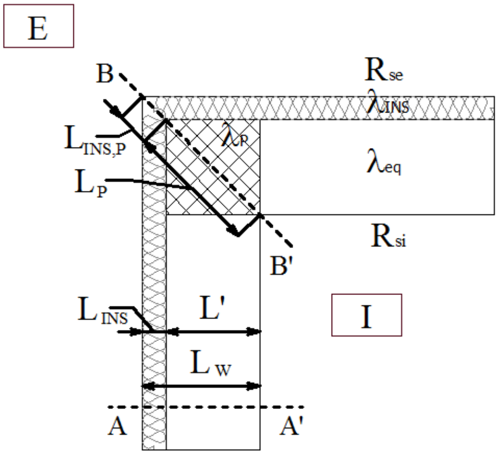
Pillar transmittance $U_P = \dfrac{1}{R_{si} + \dfrac{L_P}{\lambda_P} + R_{se}} \quad \left(\dfrac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \dfrac{1}{R_{si} + \dfrac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\dfrac{W}{m^2 \cdot K}\right)$

Validity field

$$1.52 \le U^* \le 4.59 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.47 \le U_W \le 2.09 \left(\frac{W}{m^2 \cdot K}\right)$$

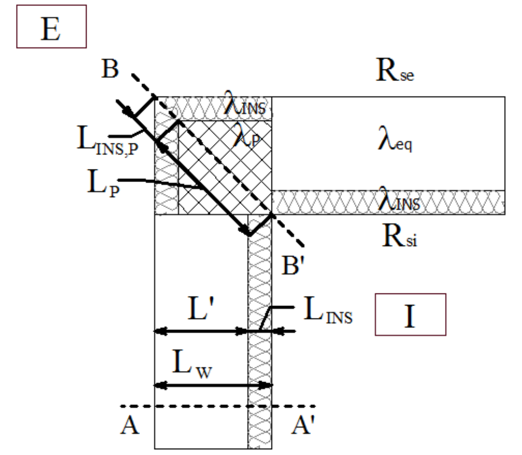
3.3.8 Projecting corner with insulated pillar

<table>
<tr><th>PC.005</th><th colspan="2">PROJECTING CORNER INSULATED OUTSIDE WITH PILLAR INSULATED OUTSIDE</th></tr>
<tr><td>Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated outside, with a pillar insulated outside in correspondence of the junction.</td><td colspan="2">

HORIZONTAL SECTION</td></tr>
<tr><th colspan="2">LINEAR THERMAL TRANSMITTANCE</th><th>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</th></tr>
<tr><td colspan="2">Related to external dimensions
$\psi_E = -0.281 + 0.147 \cdot U^* + 0.143 \cdot L_W \left(\frac{W}{m \cdot K}\right)$
Related to internal dimensions
$\psi_I = 0.385 - 0.116 \cdot U^* - 0.198 \cdot L_W \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = 0.880 - 0.319 \cdot U_P + 0.106 \cdot \lambda_{eq} (-)$</td></tr>
<tr><td colspan="2">Confidence interval
$IC_E^{95\%} = \pm 0.01 \left(\frac{W}{m \cdot K}\right)$
$IC_I^{95\%} = \pm 0.03 \left(\frac{W}{m \cdot K}\right)$</td><td>Confidence interval
$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$</td></tr>
<tr><td colspan="3">With:
Non dimensional transmittance $U^* = \frac{U_P}{U_W}$
Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field
$0.76 \le U^* \le 1.18 \quad 0.30 \le L_W \le 0.60 (m) \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.13 \le U_P \le 0.47 \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
</table>

PC.006 — PROJECTING CORNER INSULATED INSIDE WITH PILLAR INSULATED OUTSIDE

Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated inside, with a pillar insulated outside in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = -0.169 + 0.041 \cdot U^* - 0.144 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.072 + 0.012 \cdot U^* - 0.023 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.10 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.809 - 0.069 \cdot U_P - 0.057 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \;\; (-)$$

With:

Non dimensional transmittance $U^* = \dfrac{U_P}{U_W}$

Pillar transmittance

$$U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

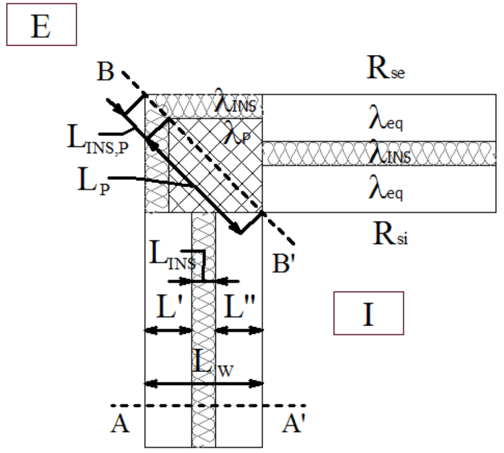
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.31 \le U^* \le 2.51 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_P \le 0.47 \left(\frac{W}{m^2 \cdot K}\right)$$

PC.007 — PROJECTING CORNER INSULATED IN THE MIDDLE WITH PILLAR INSULATED OUTSIDE

Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated in the middle, with a pillar insulated outside in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = -0.137 + 0.071 \cdot U^* + 0.355 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.084 + 0.053 \cdot U^* + 0.481 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.13 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.11 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.815 - 0.276 \cdot U_P + 0.019 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_P}{U_W}$

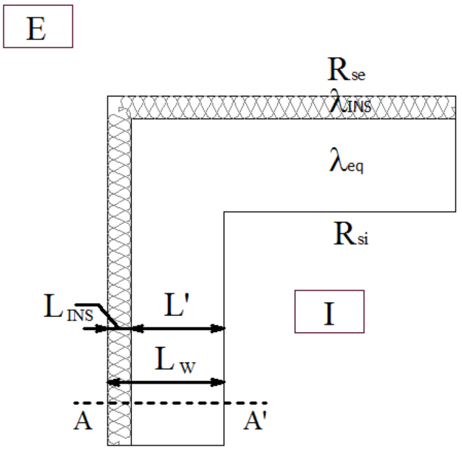
Pillar transmittance $U_P = \frac{1}{R_{si} + \frac{L_P}{\lambda_P} + \frac{L_{INS,P}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$0.77 \le U^* \le 2.51 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_P \le 0.47 \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.9 Projecting corner without pillar

PC.008	PROJECTING CORNER INSULATED OUTSIDE WITHOUT PILLAR
Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated outside, without pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.090 - 0.157 \cdot U_W + 0.032 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.047 + 0.092 \cdot U_W + 0.127 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.968 - 0.235 \cdot U_W + 0.012 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

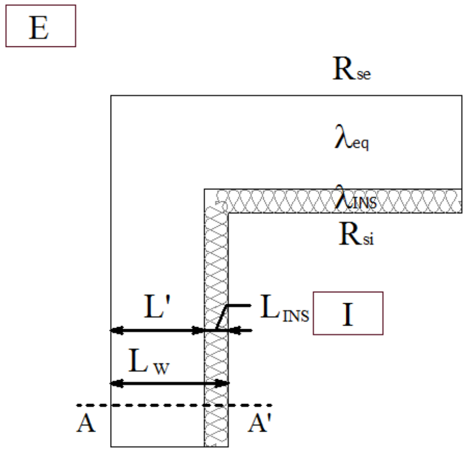
With:

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.14 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

PC.009	PROJECTING CORNER INSULATED INSIDE WITHOUT PILLAR
Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated inside, without pillar in correspondence of the junction.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.421 + 0.057 \cdot U_W + 0.037 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.154 + 0.239 \cdot U_W + 0.016 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.971 - 0.175 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.003 \quad (-)$

With:

Wall transmittance

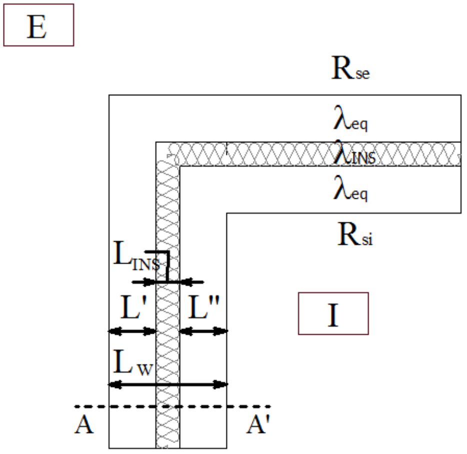
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

PC.010 PROJECTING CORNER INSULATED IN THE MIDDLE WITHOUT PILLAR

Thermal bridge characterized by the projecting squarely junction between two equal external walls, both insulated in the middle, without pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = -0.157 - 0.131 \cdot U_W - 0.010 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.110 + 0.051 \cdot U_W - 0.012 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.965 - 0.216 \cdot U_W + 0.018 \cdot \lambda_{eq} \ (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.004 \ (-)$$

With:

Wall transmittance

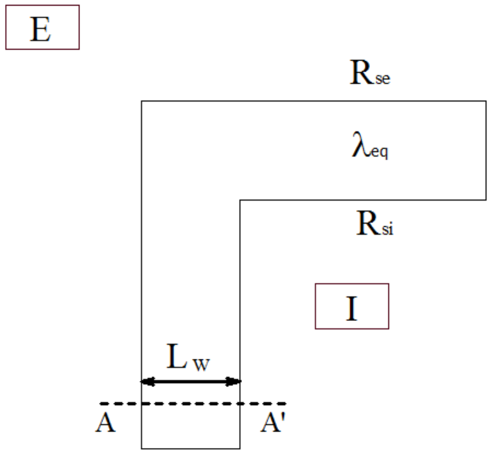
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \leq \lambda_{eq} \leq 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \leq U_W \leq 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

PC.011 UNINSULATED PROJECTING CORNER WITHOUT PILLAR

Thermal bridge characterized by the projecting squarely junction between two equal external walls, both uninsulated, without pillar in correspondence of the junction.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = -0.179 + 0.353 \cdot U_W - 2.037 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.064 - 0.073 \cdot U_W + 0.385 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.10 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.932 - 0.150 \cdot U_W - 0.046 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

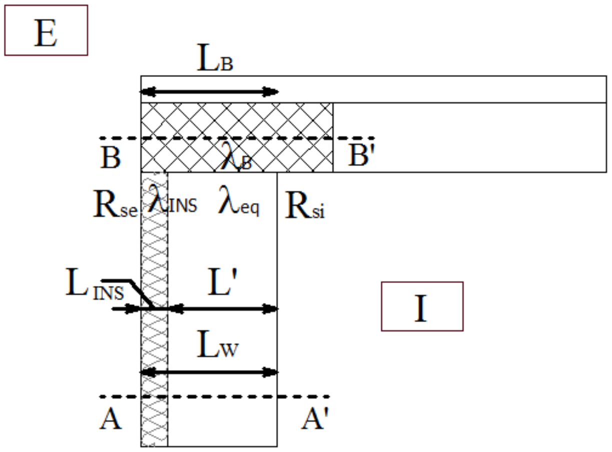
Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \leq \lambda_{eq} \leq 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.47 \leq U_W \leq 2.09 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.10 Junction between external wall and un-insulated plane roof with un-insulated beam

PR.001	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PLANE ROOF AND UNINSULATED BEAM
Thermal bridge characterized by the junction between an external wall insulated outside and an uninsulated plane roof, with an uninsulated beam.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 1.110 - 0.158 \cdot U^* + 0.077 \cdot \frac{1}{\lambda_{eq}} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.258 - 0.057 \cdot U^* + 0.147 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.550 - 0.064 \cdot U_W + 0.091 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.11 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.06 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

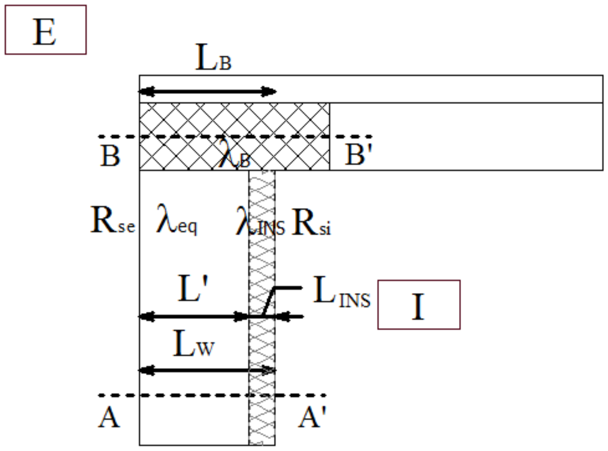
Validity field

$5.29 \le U^* \le 12.14$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

PR.002

EXTERNAL WALL INSULATED INSIDE WITH UNINSULATED PLANE ROOF AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an external wall insulated inside and an uninsulated plane roof, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.847 - 0.186 \cdot U^* + 0.173 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.136 - 0.086 \cdot U^* + 0.075 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	f_{Rsi}=0.520-0.030$\cdot U_W$-0.012$\cdot \lambda_{eq}$(−)
Confidence interval $IC_E^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance

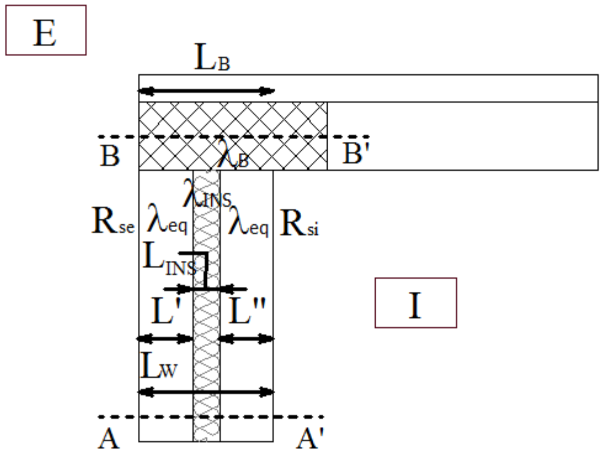
$$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

PR.003	EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED PLANE ROOF AND UNINSULATED BEAM
Thermal bridge characterized by the junction between an external wall insulated in the middle and an uninsulated plane roof, with an uninsulated beam.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 1.029 - 0.168 \cdot U^* + 0.111 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.317 - 0.068 \cdot U^* + 0.014 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.551 - 0.075 \cdot U_W + 0.086 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.10 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$.

With:

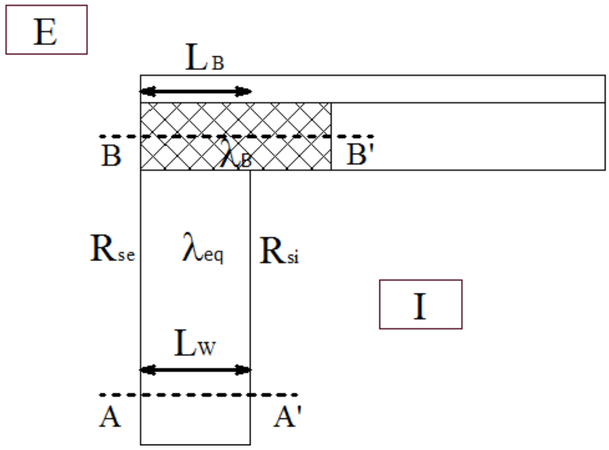
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

PR.004	UNINSULATED EXTERNAL WALL WITH UNINSULATED PLANE ROOF AND UNINSULATED BEAM
Thermal bridge characterized by the junction between an uninsulated external wall and an uninsulated plane roof, with an uninsulated beam.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.789 - 1.859 \cdot L_W - 0.523 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.034 - 0.224 \cdot L_W + 0.027 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.547 - 0.055 \cdot U_W + 0.136 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.07 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$

With:

Wall transmittance $U_W = \dfrac{1}{R_{si} + \dfrac{L_W}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

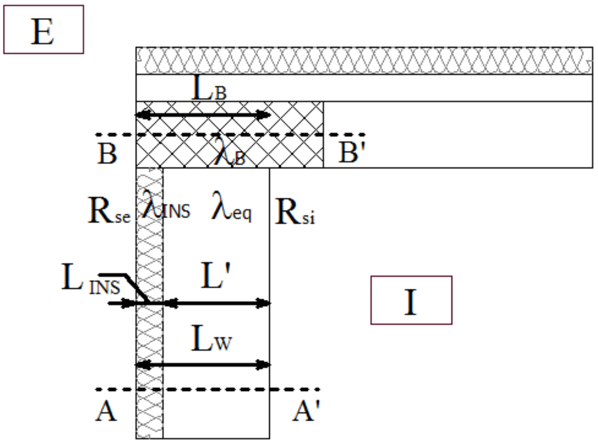
Validity field

$0.25 \le L_W \le 0.45 \ (m)$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.47 \le U_W \le 2.09 \left(\frac{W}{m^2 \cdot K}\right)$

3.3.11 Junction between external wall and insulated plane roof with un-insulated beam

PR.005	EXTERNAL WALL INSULATED OUTSIDE WITH INSULATED PLANE ROOF AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an external wall insulated outside and an insulated plane roof, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE

Related to external dimensions

$$\psi_E = 0.429 - 0.050 \cdot U^* + 0.018 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.785 - 0.041 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.584 + 0.346 \cdot L' + 0.060 \cdot \lambda_{eq} \; (-)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

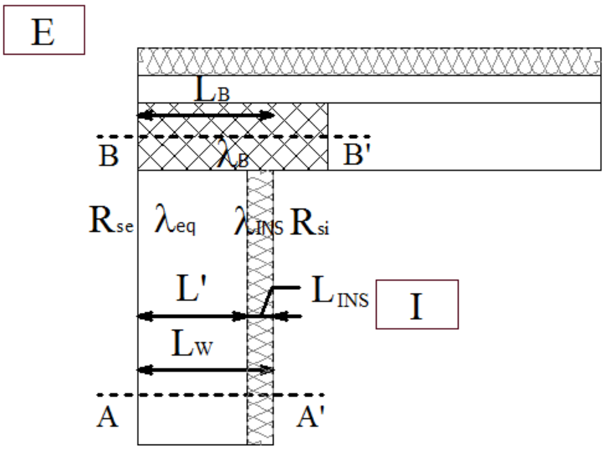
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.25 \le L' \le 0.45 \; (m)$

PR.006 — EXTERNAL WALL INSULATED INSIDE WITH INSULATED PLANE ROOF AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an external wall insulated inside and an insulated plane roof, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.292 - 0.057 \cdot U^* + 0.053 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.645 - 0.046 \cdot U^* + 0.030 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.597 + 0.255 \cdot L' - 0.045 \cdot \lambda_{eq} \ (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

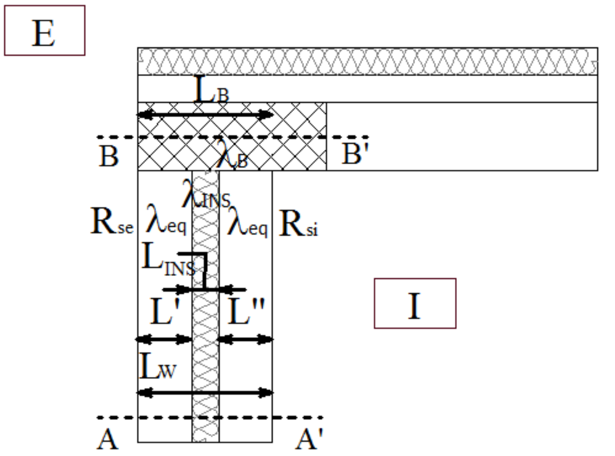
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L' \le 0.45 \quad (m)$

PR.007	EXTERNAL WALL INSULATED IN THE MIDDLE WITH INSULATED PLANE ROOF AND UNINSULATED BEAM
Thermal bridge characterized by the junction between an external wall insulated in the middle and an insulated plane roof, with an uninsulated beam.	
	VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.387 - 0.054 \cdot U^* + 0.035 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.741 - 0.044 \cdot U^* + 0.013 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.583 + 0.341 \cdot (L' + L'') + 0.046 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$.

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance
$$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

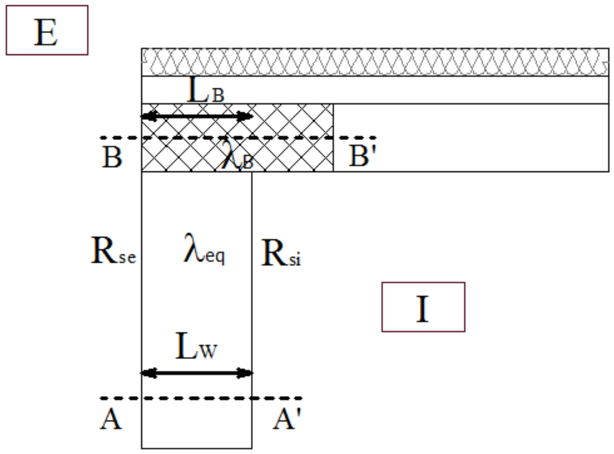
Wall transmittance
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le (L' + L'') \le 0.45 \quad (m)$

PR.008 — UNINSULATED EXTERNAL WALL WITH INSULATED PLANE ROOF AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an uninsulated external wall and an insulated plane roof, with an uninsulated beam.



VERTICAL SECTION

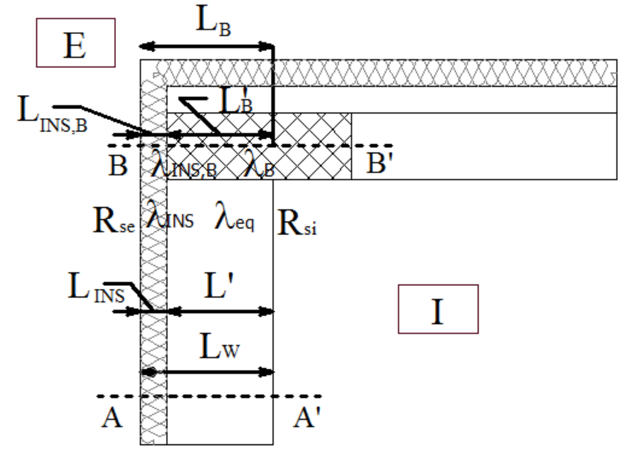
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.219 - 0.249 \cdot L_W - 0.750 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.664 - 0.561 \cdot L_W - 0.016 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.555 + 0.384 \cdot L_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

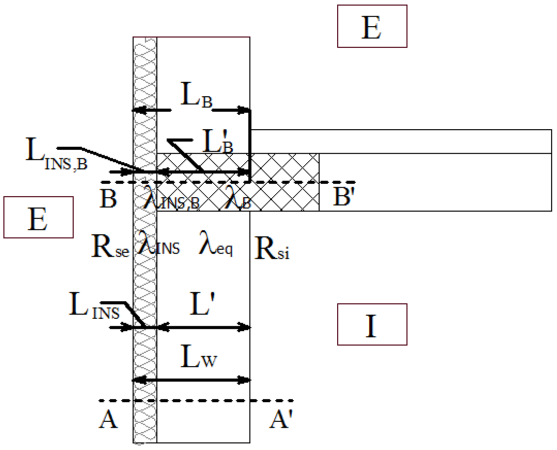
Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L_W \le 0.45 \quad (m)$$

3.3.12 Junction between external wall and insulated plane roof with insulated beam

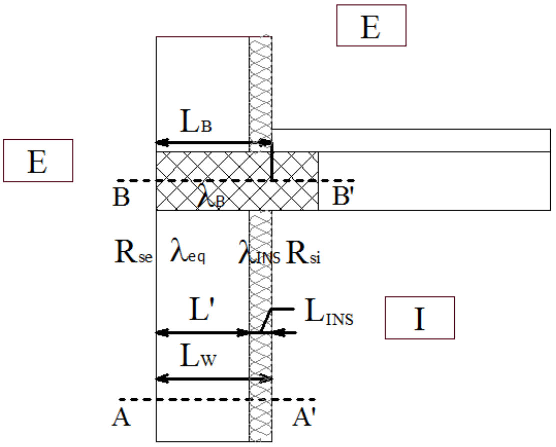
<table>
<tr><th>PR.009</th><th colspan="2">EXTERNAL WALL INSULATED OUTSIDE WITH INSULATED PLANE ROOF AND INSULATED BEAM</th></tr>
<tr><td>Thermal bridge characterized by the junction between an external wall insulated outside and an insulated plane roof, with an insulated beam.</td><td colspan="2">
VERTICAL SECTION</td></tr>
<tr><th colspan="2">LINEAR THERMAL TRANSMITTANCE</th><th>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</th></tr>
<tr><td colspan="2">Related to external dimensions
$\psi_E = -0.360 - 0.053 \cdot U^* - 0.023 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$
Related to internal dimensions
$\psi_I = 0.242 - 0.280 \cdot U^* + 0.008 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = 0.819 + 0.136 \cdot L' + 0.035 \cdot \lambda_{eq} \, (-)$</td></tr>
<tr><td colspan="2">Confidence interval
$IC_E^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$
$IC_I^{95\%} = \pm 0.07 \quad \left(\frac{W}{m \cdot K}\right)$</td><td>Confidence interval
$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$</td></tr>
<tr><td colspan="3">With:
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$
Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L'_B}{\lambda_B} + \frac{L_{INS,B}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field
$1.08 \le U^* \le 1.62 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L' \le 0.45 \quad (m)$</td></tr>
</table>

3.3.13 Junction between external wall and un-insulated plane roof with parapet

PR.010	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PLANE ROOF, INSULATED BEAM AND INSULATED PARAPET
Thermal bridge characterized by the junction between an external wall insulated outside and an uninsulated plane roof, with an insulated beam and an insulated parapet.	 VERTICAL SECTION
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.473 - 1.820 \cdot L_W + 0.351 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.685 - 0.441 \cdot L_W + 0.407 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.631 + 0.073 \cdot L' + 0.014 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.06 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.003 \ (-)$
With:	
Validity field $0.23 \leq \lambda_{eq} \leq 0.81 \left(\frac{W}{m \cdot K}\right)$ $0.30 \leq L_W \leq 0.60 \ (m)$ $0.25 \leq L' \leq 0.45 \ (m)$	

PR.011	EXTERNAL WALL INSULATED INSIDE WITH UNINSULATED PLANE ROOF, UNINSULATED BEAM AND INSULATED PARAPET

Thermal bridge characterized by the junction between an external wall insulated inside and an uninsulated plane roof, with an uninsulated beam and an insulated parapet.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.918 + 0.002 \cdot U^* - 2.734 \cdot L_W \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 1.180 - 0.008 \cdot U^* - 1.220 \cdot L_W \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.490 + 0.186 \cdot L' - 0.043 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

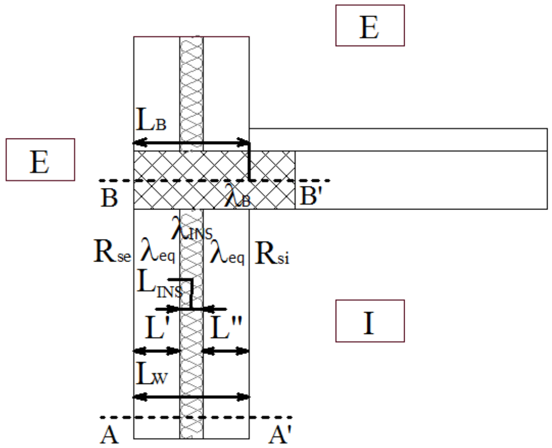
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$5.29 \le U^* \le 12.14 \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.30 \le L_W \le 0.60 \ (m) \quad 0.25 \le L' \le 0.45 \ (m)$$

PR.012	EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED PLANE ROOF, UNINSULATED BEAM AND INSULATED PARAPET

Thermal bridge characterized by the junction between an external wall insulated in the middle and an uninsulated plane roof, with an uninsulated beam and an insulated parapet.



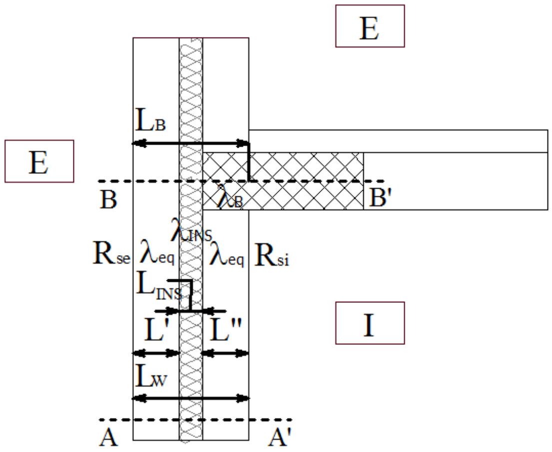
VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.858 - 2.491 \cdot L_W + 0.269 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.070 - 1.112 \cdot L_W + 0.325 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.495 + 0.224 \cdot (L' + L'') + 0.036 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

Validity field

$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.30 \le L_W \le 0.60 \quad (m) \qquad 0.25 \le (L' + L'') \le 0.45 \quad (m)$

<table>
<tr><td>PR.013</td><td colspan="2">EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED PLANE ROOF, INSULATED BEAM AND INSULATED PARAPET</td></tr>
<tr><td>Thermal bridge characterized by the junction between an external wall insulated in the middle and an uninsulated plane roof, with an insulated beam and an insulated parapet.</td><td colspan="2">

VERTICAL SECTION</td></tr>
<tr><td colspan="2">LINEAR THERMAL TRANSMITTANCE</td><td>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</td></tr>
<tr><td colspan="2">Related to external dimensions

$$\psi_E = 0.514 - 1.520 \cdot L_W + 0.223 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.726 - 0.141 \cdot L_W + 0.280 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$</td><td>$$f_{Rsi} = 0.653 + 0.048 \cdot (L' + L'') + 0.011 \cdot \lambda_{eq} \, (-)$$</td></tr>
<tr><td colspan="2">Confidence interval

$$IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$$</td><td>Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.002 \quad (-)$$</td></tr>
<tr><td colspan="3">With:

Non dimensional transmittance $$U^* = \frac{U_B}{U_W}$$

Beam transmittance $$U_B = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

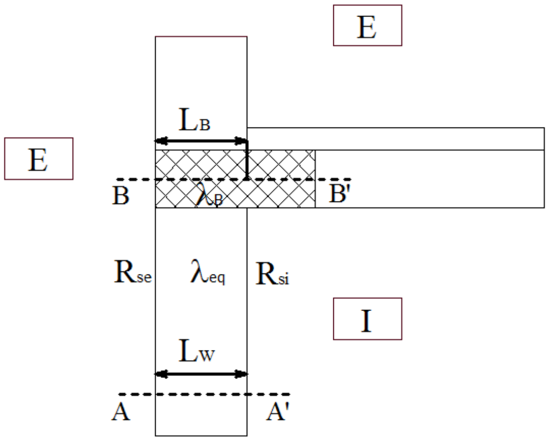
Wall transmittance $$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$</td></tr>
<tr><td colspan="3">Validity field

$0.23 \le \lambda_{eq} \le 0.81 \; \left(\frac{W}{m \cdot K}\right)$ $0.30 \le L_W \le 0.60 \; (m)$ $0.25 \le (L' + L'') \le 0.45 \; (m)$</td></tr>
</table>

PR.014

UNINSULATED EXTERNAL WALL WITH UNINSULATED PLANE ROOF AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an uninsulated external wall and an insulated plane roof, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.774 - 2.034 \cdot L_W - 0.449 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 1.136 - 1.177 \cdot L_W + 0.101 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.07 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.487 + 0.226 \cdot L_W \, (-)$$

Confidence interval

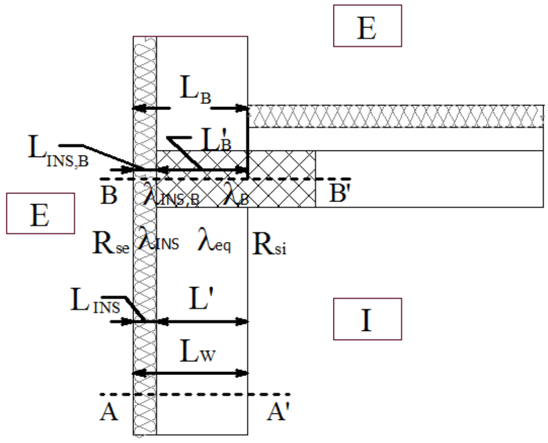
$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L_W \le 0.45 \quad (m)$$

3.3.14 Junction between external wall and insulated plane roof with parapet

PR.015	EXTERNAL WALL INSULATED OUTSIDE WITH INSULATED PLANE ROOF, INSULATED BEAM AND INSULATED PARAPET
Thermal bridge characterized by the junction between an external wall insulated outside and an insulated plane roof, with an insulated beam and an insulated parapet.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.728 - 0.438 \cdot L_W + 0.328 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.198 + 0.215 \cdot L_W + 0.468 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.844 + 0.057 \cdot L' - 0.063 \cdot \lambda_{eq} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.09 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

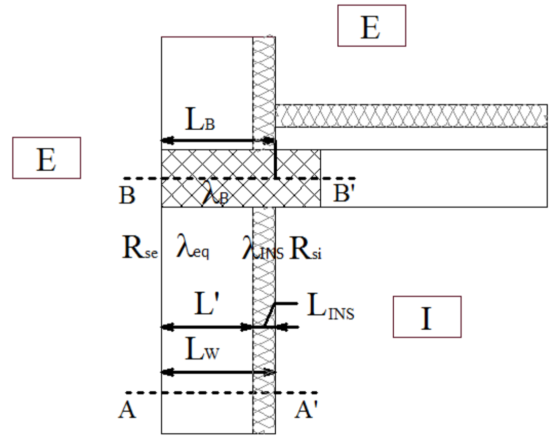
With:

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.30 \le L_W \le 0.60 \quad (m) \qquad 0.25 \le L' \le 0.45 \quad (m)$$

PR.016	EXTERNAL WALL INSULATED INSIDE WITH INSULATED PLANE ROOF, UNINSULATED BEAM AND INSULATED PARAPET

Thermal bridge characterized by the junction between an external wall insulated inside and an insulated plane roof, with an uninsulated beam and an insulated parapet.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.366 - 0.012 \cdot U^* - 0.635 \cdot L_W \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 0.716 - 0.025 \cdot U^* - 0.321 \cdot L_W \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.605 + 0.251 \cdot L' - 0.076 \cdot \lambda_{eq} \; (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

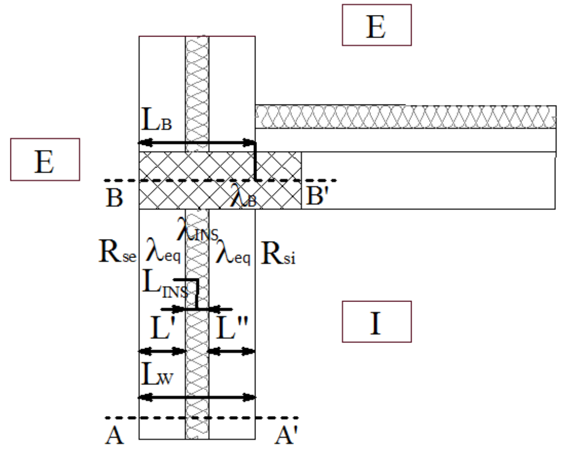
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$$5.29 \le U^* \le 12.14 \quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.30 \le L_W \le 0.60 \; (m) \quad 0.25 \le L' \le 0.45 \; (m)$$

PR.017	EXTERNAL WALL INSULATED IN THE MIDDLE WITH INSULATED PLANE ROOF, UNINSULATED BEAM AND INSULATED PARAPET
Thermal bridge characterized by the junction between an external wall insulated in the middle and an insulated plane roof, with an uninsulated beam and an insulated parapet.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.434 - 0.044 \cdot U^* + 0.053 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.676 - 0.034 \cdot U^* + 0.173 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.613 + 0.266 \cdot (L'+L")(-)$
Confidence interval $IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

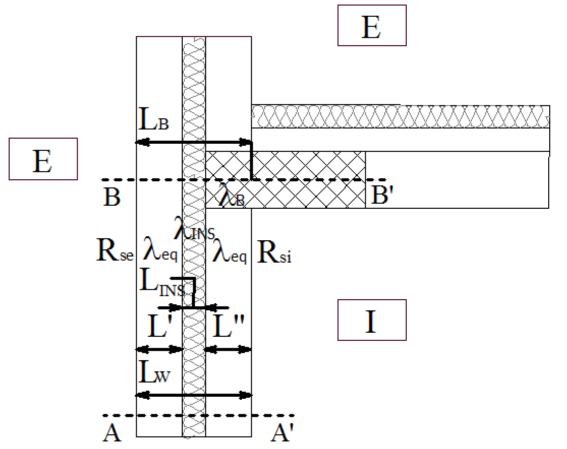
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L"}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le (L'+L") \le 0.45 \; (m)$

PR.018	EXTERNAL WALL INSULATED IN THE MIDDLE WITH INSULATED PLANE ROOF, INSULATED BEAM AND INSULATED PARAPET
Thermal bridge characterized by the junction between an external wall insulated in the middle and an insulated plane roof, with an insulated beam and an insulated parapet.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = -0.512 - 0.027\cdot L_W + 0.292\cdot\lambda_{eq} \quad \left(\frac{W}{m\cdot K}\right)$ Related to internal dimensions $\psi_I = -0.230 + 0.107\cdot L_W + 0.367\cdot\lambda_{eq} \quad \left(\frac{W}{m\cdot K}\right)$	$f_{Rsi} = 0.874 + 0.062\cdot(L'+L'') - 0.067\cdot\lambda_{eq}\,(-)$
Confidence interval $IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m\cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m\cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$.

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $$U_B = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2\cdot K}\right)$$

Wall transmittance $$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2\cdot K}\right)$$

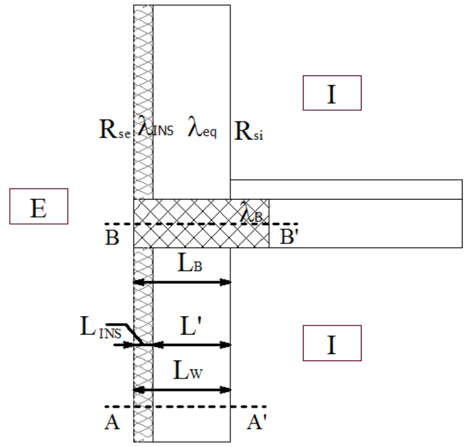
Validity field

$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m\cdot K}\right) \qquad 0.30 \le L_W \le 0.60 \quad (m) \qquad 0.25 \le (L'+L'') \le 0.45 \quad (m)$

3.3.15 Junction between external wall and floor with un-insulated beam

FL.001	EXTERNAL WALL INSULATED OUTSIDE WITH FLOOR AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an external wall insulated outside and a floor, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 1.761 - 0.038 \cdot U^* - 1.295 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 2.068 - 0.056 \cdot U^* - 1.329 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.124 - 0.101 \cdot U_B - 0.010 \cdot \frac{1}{\lambda_{eq}} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.21 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.19 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

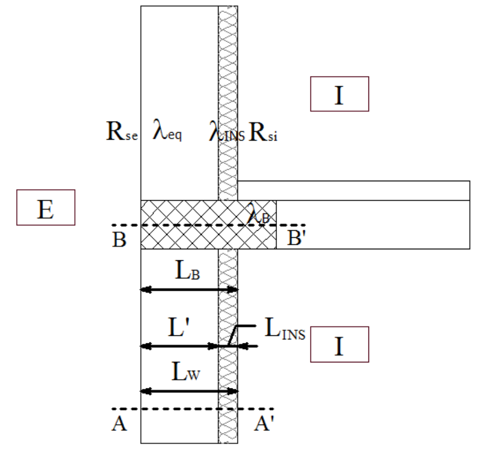
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

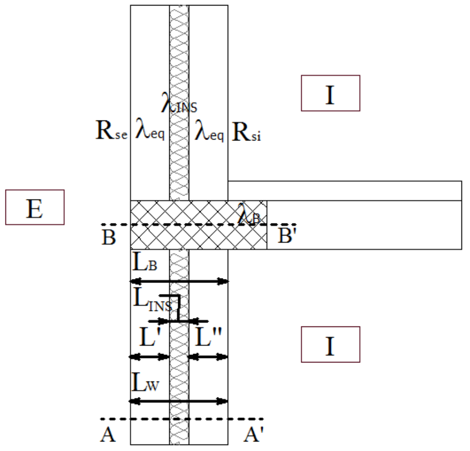
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.75 \le U^* \le 14.49 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 2.47 \le U_B \le 3.32 \quad \left(\frac{W}{m^2 \cdot K}\right)$

<table>
<tr><th>FL.002</th><th colspan="2">EXTERNAL WALL INSULATED INSIDE WITH FLOOR AND UNINSULATED BEAM</th></tr>
<tr><td>Thermal bridge characterized by the junction between an external wall insulated inside and a floor, with an uninsulated beam.</td><td colspan="2">

VERTICAL SECTION</td></tr>
<tr><td colspan="2">LINEAR THERMAL TRANSMITTANCE</td><td>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</td></tr>
<tr><td colspan="2">Related to external dimensions
$\psi_E = 0.934 - 0.037 \cdot U^* + 0.018 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$
Related to internal dimensions
$\psi_I = 1.215 - 0.056 \cdot U^* + 0.025 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = 0.898 - 0.076 \cdot U_B + 0.014 \cdot \frac{1}{\lambda_{eq}} \, (-)$</td></tr>
<tr><td colspan="2">Confidence interval
$IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$
$IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$</td><td>Confidence interval
$IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$
.</td></tr>
<tr><td colspan="3">With:
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$
Beam transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field
$5.75 \le U^* \le 14.49 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 2.47 \le U_B \le 3.32 \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
</table>

FL.003	EXTERNAL WALL INSULATED IN THE MIDDLE WITH FLOOR AND UNINSULATED BEAM
Thermal bridge characterized by the junction between an external wall insulated in the middle and a floor, with an uninsulated beam.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 1.612 - 0.039 \cdot U^* - 1.16 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.919 - 0.057 \cdot U^* - 1.194 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.093 - 0.100 \cdot U_B - 0.005 \cdot \frac{1}{\lambda_{eq}} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.21 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.20 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$

With:

Non dimensional transmittance $$U^* = \frac{U_B}{U_W}$$

Beam transmittance $$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

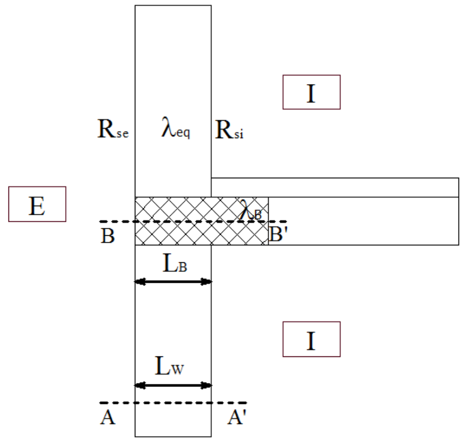
Wall transmittance $$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$5.75 \le U^* \le 14.49 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 2.47 \le U_B \le 3.32 \left(\frac{W}{m^2 \cdot K}\right)$

FL.004 — UNINSULATED EXTERNAL WALL WITH FLOOR AND UNINSULATED BEAM

Thermal bridge characterized by the junction between an uninsulated external wall and a floor, with an uninsulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.900 - 0.490 \cdot L_W - 0.526 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.322 - 1.457 \cdot L_W + 0.116 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.981 - 0.091 \cdot U_B + 0.005 \cdot \frac{1}{\lambda_{eq}} \; (-)$
Confidence interval $IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \; (-)$

With:

Beam transmittance

$$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

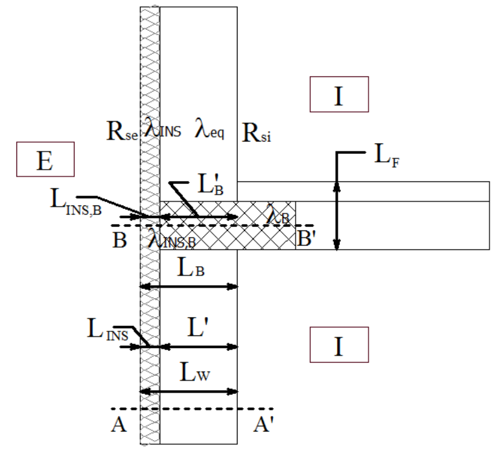
Validity field

$$0.25 \le L_W \le 0.45 \; (m) \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 2.47 \le U_B \le 3.32 \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.16 Junction between external wall and floor with insulated beam

FL.005 **EXTERNAL WALL INSULATED OUTSIDE WITH FLOOR AND INSULATED BEAM**

Thermal bridge characterized by the junction between an external wall insulated outside and a floor, with an insulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = -0.042 + 0.089 \cdot U_W + 0.017 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = -0.042 + \left(L_F + 0.089\right) \cdot U_W + 0.017 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.966 - 0.130 \cdot U_W + 0.039 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

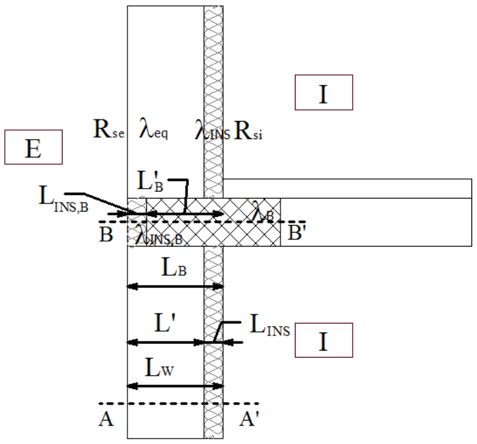
With:

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

FL.006	EXTERNAL WALL INSULATED INSIDE WITH FLOOR AND INSULATED BEAM
Thermal bridge characterized by the junction between an external wall insulated inside and a floor, with an insulated beam.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.326 + 0.288 \cdot U^* - 0.119 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = -0.076 + 0.875 \cdot U^* - 0.211 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.939 - 0.153 \cdot U_W - 0.152 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$.

With:

Non dimensional transmittance	$U^* = \frac{U_B}{U_W}$
Beam transmittance	$U_B = \frac{1}{R_{si} + \frac{L'_B}{\lambda_B} + \frac{L_{INS,B}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$
Wall transmittance	$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

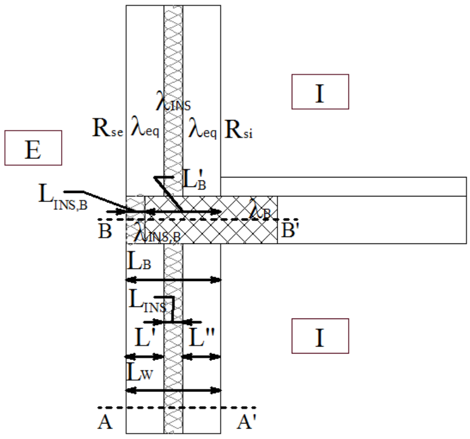
Validity field

$1.08 \le U^* \le 1.62 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

FL.007

EXTERNAL WALL INSULATED IN THE MIDDLE WITH FLOOR AND INSULATED BEAM

Thermal bridge characterized by the junction between an external wall insulated in the middle and a floor, with an insulated beam.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.112 + 0.428 \cdot U^* - 0.127 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = -0.290 + 1.015 \cdot U^* - 0.219 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.949 - 0.167 \cdot U_W - 0.033 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.12 \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

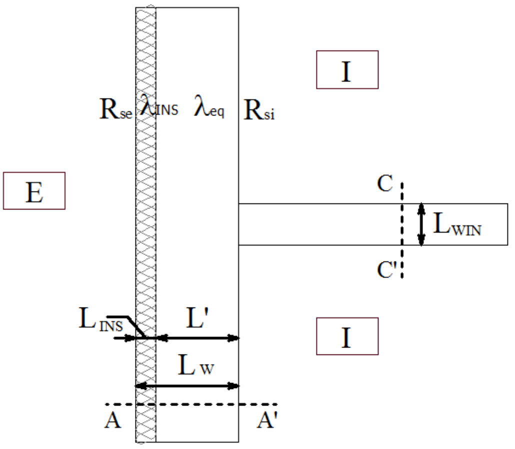
Beam transmittance
$$U_B = \frac{1}{R_{si} + \frac{L'_B}{\lambda_B} + \frac{L_{INS,B}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

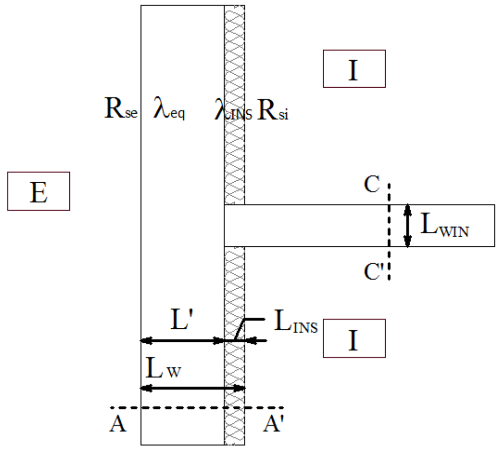
$1.08 \le U^* \le 1.62$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

3.3.17 Junction between external and internal walls

INT.001	EXTERNAL WALL INSULATED OUTSIDE WITH INTERNAL WALL
Thermal bridge characterized by the junction between an external wall insulated outside and an internal wall.	 HORIZONTAL SECTION
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0 \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = L_{WIN} \cdot U_W \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.000 - 0.130 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.00 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.00 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.00 \quad (-)$
With: Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$	
Validity field $0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$	

INT.002	EXTERNAL WALL INSULATED INSIDE WITH INTERNAL WALL

Thermal bridge characterized by the junction between an external wall insulated inside and an internal wall.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.105 \cdot U_W + 0.157 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = \left(L_{WIN} + 0.105\right) \cdot U_W + 0.157 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.998 - 0.234 \cdot U_W - 0.107 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

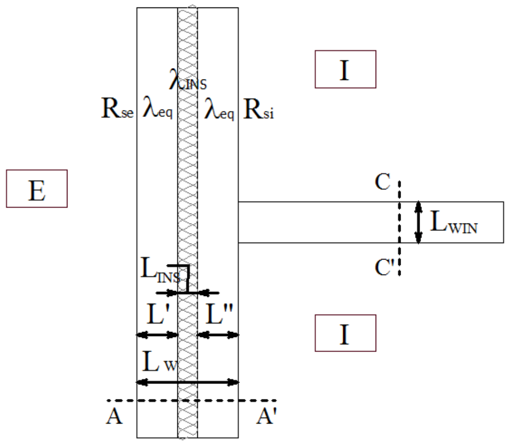
With:

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

INT.003	EXTERNAL WALL INSULATED IN THE MIDDLE WITH INTERNAL WALL
Thermal bridge characterized by the junction between an external wall insulated in the middle and an internal wall.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0 \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = \left(L_{WIN} + 0.030\right) \cdot U_W \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.001 - 0.132 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.00 \quad (-)$.

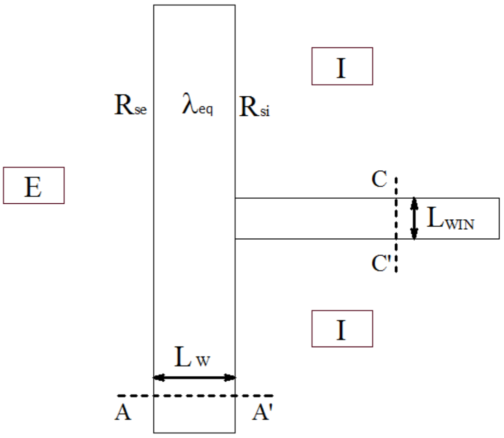
With:

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

INT.004	UNINSULATED EXTERNAL WALL WITH INTERNAL WALL
Thermal bridge characterized by the junction between an uninsulated external wall and an internal wall.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0 \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = L_{WIN} \cdot U_W \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.000\text{-}0.130 \cdot U_W (-)$
Confidence interval $IC_E^{95\%} = \pm 0.00 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.00 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.00 \quad (-)$

With:

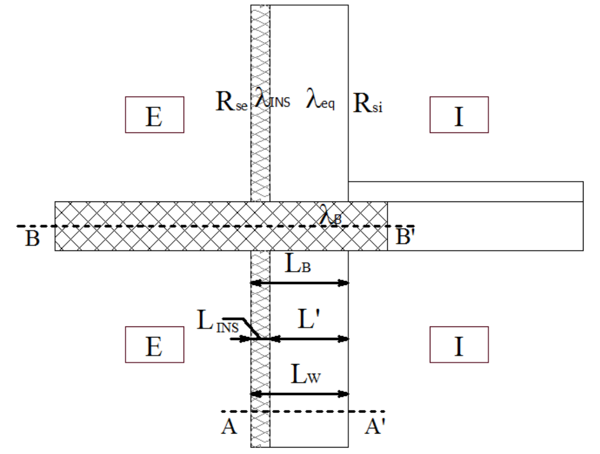
Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.47 \le U_W \le 2.09 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

3.3.18 Junction between external wall and un-insulated balcony

BALC.001	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED BALCONY
Thermal bridge characterized by the junction between an external wall insulated outside and an uninsulated balcony.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.985 - 0.040 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 1.280 - 0.061 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.644 + 0.397 \cdot L' + 0.056 \cdot \lambda_{eq} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.07 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

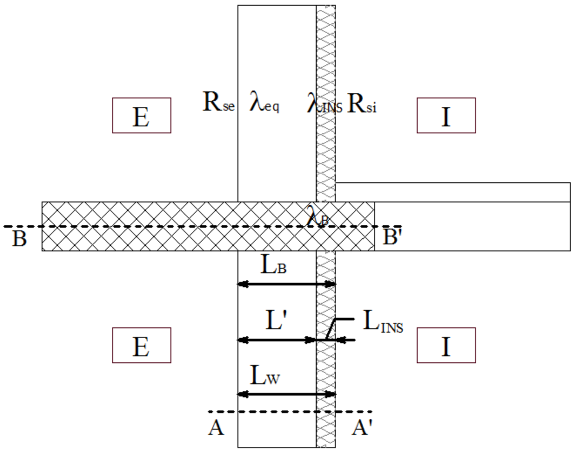
Validity field

$5.29 \le U^* \le 12.14 \qquad 0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L' \le 0.45 \quad (m)$

BALC.002

EXTERNAL WALL INSULATED INSIDE WITH UNINSULATED BALCONY

Thermal bridge characterized by the junction between an external wall insulated inside and an uninsulated balcony.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.938 - 0.045 \cdot U^* + 0.016 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 1.238 - 0.069 \cdot U^* + 0.027 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.668 + 0.289 \cdot L' - 0.086 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

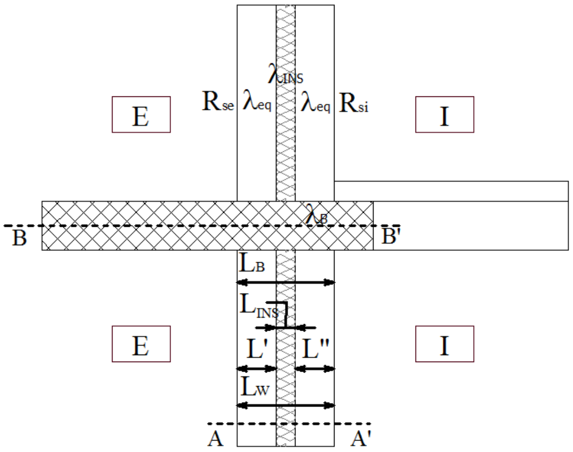
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.25 \le L' \le 0.45 \ (m)$

BALC.003 — EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED BALCONY

Thermal bridge characterized by the junction between an external wall insulated in the middle and an uninsulated balcony.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 1.016 - 0.043 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 1.310 - 0.065 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.646 + 0.399 \cdot (L' + L'') + 0.023 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

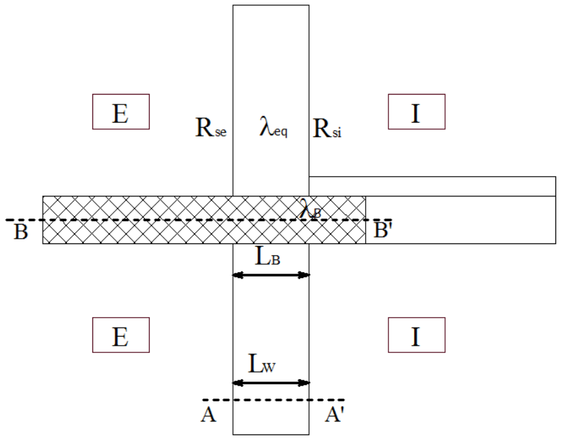
Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$5.29 \le U^* \le 12.14$ $\quad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $\quad 0.25 \le L' + L'' \le 0.45 \; (m)$

BALC.004 UNINSULATED EXTERNAL WALL WITH UNINSULATED BALCONY

Thermal bridge characterized by the junction between an uninsulated external wall and an uninsulated balcony.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE

Related to external dimensions

$$\psi_E = 0.803 - 0.346 \cdot L_W - 0.519 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Related to internal dimensions

$$\psi_I = 1.225 - 1.312 \cdot L_W + 0.113 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.632 + 0.404 \cdot L_W - 0.046 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

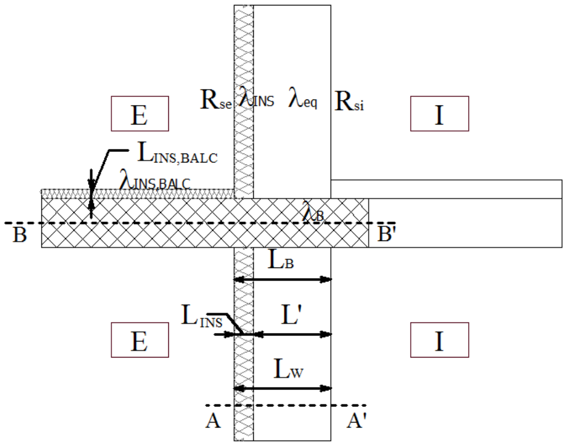
.

With:

Validity field

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.25 \le L_W \le 0.45 \quad (m)$$

3.3.19 Junction between external wall and insulated balcony

BALC.005	EXTERNAL WALL INSULATED OUTSIDE WITH BALCONY UPPER INSULATED
Thermal bridge characterized by the junction between an external wall insulated outside and a balcony upper insulated.	 VERTICAL SECTION
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.683 - 0.069 \cdot U^* - 0.074 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.941 - 0.133 \cdot U^* + 0.063 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.956 - 0.220 \cdot U_W - 0.017 \cdot \frac{1}{\lambda_{eq}} \ (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance

$$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + \frac{L_{INS,BALC}}{\lambda_{INS,BALC}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

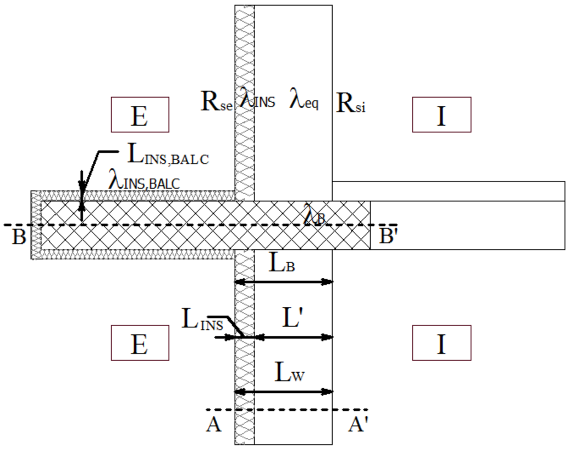
Validity field

$1.10 \le U^* \le 3.39 \qquad 0.23 \le \lambda_{eq} \le 0.81 \ \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \ \left(\frac{W}{m^2 \cdot K}\right)$

BALC.006

EXTERNAL WALL INSULATED OUTSIDE WITH BALCONY TOTALLY INSULATED

Thermal bridge characterized by the junction between an external wall insulated outside and a balcony totally insulated.



VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.305 + 0.007 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.554 - 0.056 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.958 - 0.120 \cdot U_W - 0.012 \cdot \frac{1}{\lambda_{eq}} \ (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.004 \ (-)$

With:

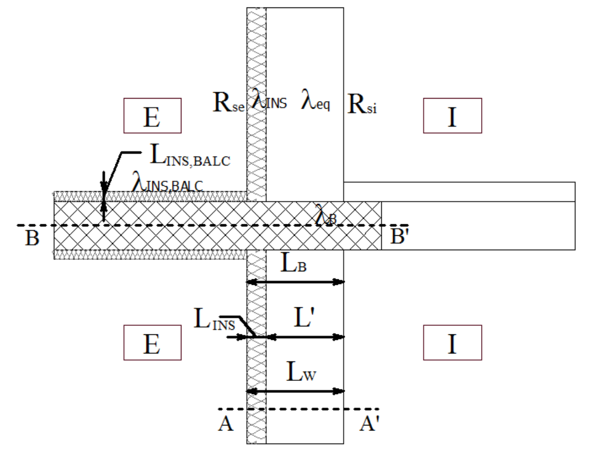
Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance $U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + \frac{L_{INS,BALC}}{\lambda_{INS,BALC}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$

Validity field

$1.10 \le U^* \le 3.39 \qquad 0.23 \le \lambda_{eq} \le 0.81 \ \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \ \left(\frac{W}{m^2 \cdot K}\right)$

BALC.007	EXTERNAL WALL INSULATED OUTSIDE WITH BALCONY INSULATED UP AND DOWN
Thermal bridge characterized by the junction between an external wall insulated outside and a balcony insulated up and down.	 VERTICAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
Related to external dimensions $\psi_E = 0.317 + 0.005 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$ Related to internal dimensions $\psi_I = 0.566 - 0.058 \cdot U^* \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.958 - 0.122 \cdot U_W - 0.012 \cdot \frac{1}{\lambda_{eq}} \quad (-)$
Confidence interval $IC_E^{95\%} = \pm 0.04 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.004 \quad (-)$

With:

Non dimensional transmittance $U^* = \frac{U_B}{U_W}$

Balcony transmittance

$$U_B = \frac{1}{R_{si} + \frac{L_B}{\lambda_B} + \frac{L_{INS,BALC}}{\lambda_{INS,BALC}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Wall transmittance

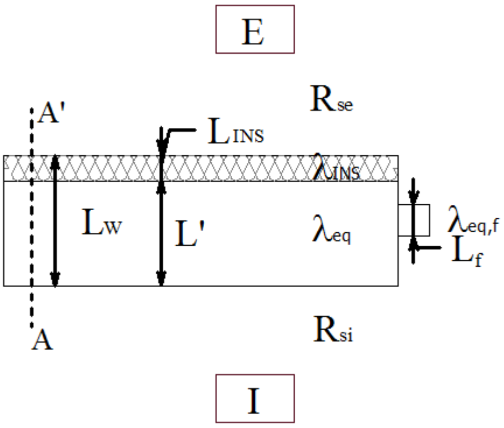
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$1.10 \le U^* \le 3.39 \qquad 0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$

3.3.20 Junction between external wall and window positioned in the middle

WIND.001	EXTERNAL WALL INSULATED OUTSIDE WITH WINDOW IN THE MIDDLE
Thermal bridge characterized by the junction between an external wall insulated outside and a window positioned in the middle.	HORIZONTAL SECTION



LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.781 - 0.052 \cdot \lambda_{eq,f} - 0.065 \cdot \lambda_{eq} \; (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

With:

$$\psi_1 = 0.083 - 0.308 \cdot U_W + 0.533 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.101 - 0.281 \cdot U_W + 0.624 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

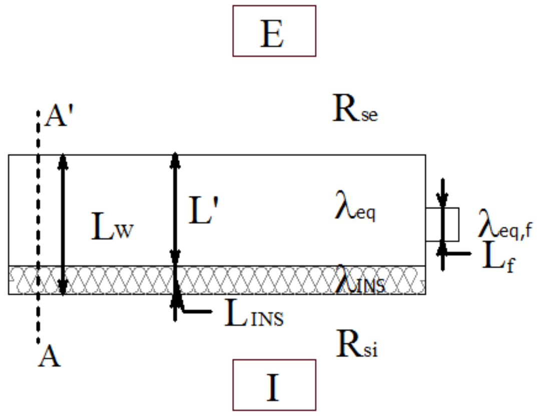
$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right)$ $\quad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$

$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right)$ $\quad 0.17 \le \lambda_{eq,f} \le 5.08 \quad \left(\frac{W}{m \cdot K}\right)$

WIND.002

EXTERNAL WALL INSULATED INSIDE WITH WINDOW IN THE MIDDLE

Thermal bridge characterized by the junction between an external wall insulated inside and a window positioned in the middle.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = 0.080 - 0.273 \cdot U_W + 0.409 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.04 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.04 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

$$f_{Rsi1} = 0.772 + 0.091 \cdot L' - 0.334 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.491 + 0.051 \cdot L' - 0.163 \cdot \lambda_{eq} (-)$$

Wall transmittance
$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance
$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

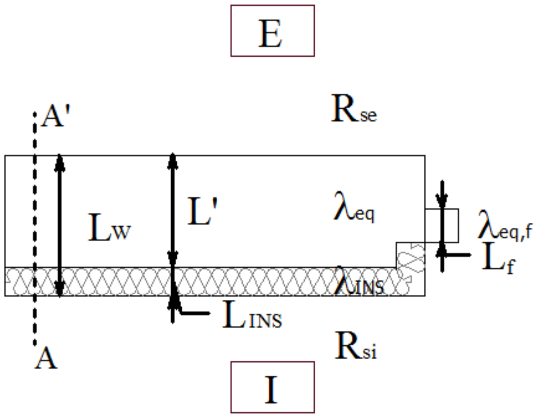
$$0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L' \le 0.45 \ (m)$$

WIND.003

EXTERNAL WALL WITH FOLDING INSULATION INSIDE AND WINDOW IN THE MIDDLE

Thermal bridge characterized by the junction between an external wall with a folding insulation inside and a window positioned in the middle.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = 0.043 - 0.063 \cdot U_W + 0.146 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.02 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.02 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

$$f_{Rsi1} = 0.776 - 0.035 \cdot L' - 0.241 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.509 - 0.016 \cdot L' - 0.068 \cdot \lambda_{eq} (-)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

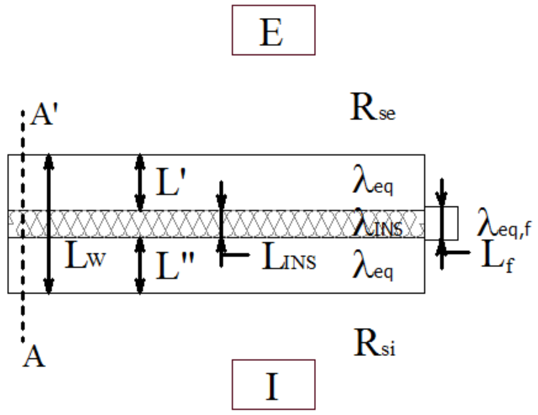
$$0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L' \le 0.45 \ (m)$$

WIND.004

EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW IN THE MIDDLE

Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned in the middle.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}\left(\psi_2 - \psi_1\right) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$$

With:

$$\psi_1 = 0 \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = \begin{cases} 0 & \text{se } L_{INS} > L_f \\ 0.156 \cdot \lambda_{eq} + 0.040 & \text{se } L_{INS} < L_f \end{cases} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi1} = 0.859 - 0.083 \cdot (L' + L") + 0.020 \cdot \lambda_{eq} (-)$$

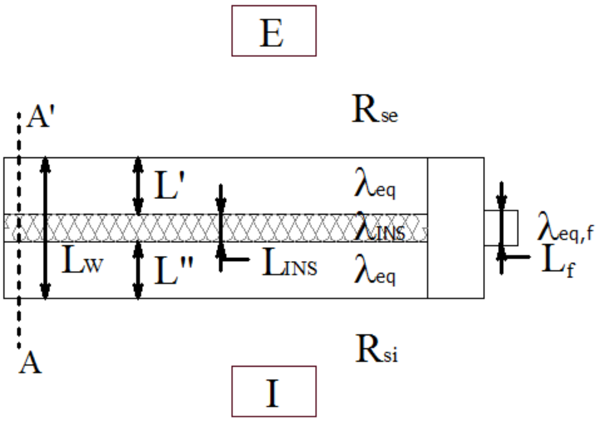
$$f_{Rsi2} = 0.415 + 0.318 \cdot (L' + L") (-)$$

Frame transmittance $$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad 0.25 \le (L' + L") \le 0.45 \quad (m)$$

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right)$$

WIND.005	EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW IN THE MIDDLE WITH LINTEL
Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned in the middle with lintel.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = 0.538 - 0.026 \cdot \lambda_{eq,f} + 0.010 \cdot \lambda_{eq} \, (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

With:

$$\psi_1 = 0.801 + 0.191 \cdot U_W + 0.076 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.879 + 0.191 \cdot U_W + 0.076 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

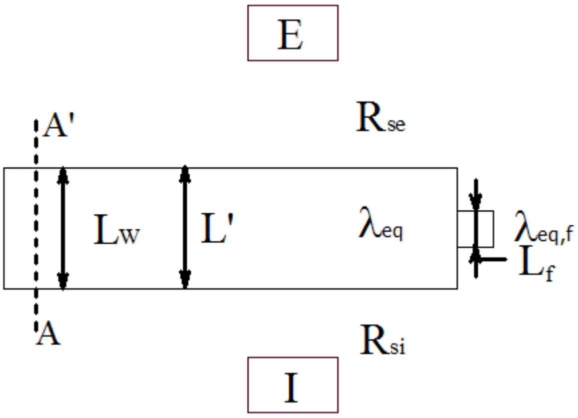
Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \qquad 0.17 \le \lambda_{eq,f} \le 5.08 \quad \left(\frac{W}{m \cdot K}\right)$$

WIND.006	UNINSULATED EXTERNAL WALL WITH WINDOW IN THE MIDDLE
Thermal bridge characterized by the junction between an uninsulated external wall and a window positioned in the middle.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = \frac{U_f - 1.90}{3.60}(f_{Rsi2} - f_{Rsi1}) + f_{Rsi1} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.02 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$

With:

$$\psi_1 = 0.049 - 0.101 \cdot U_W - 0.359 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.085 - 0.099 \cdot U_W + 0.399 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi1} = 0.789 - 0.012 \cdot L_W - 0.200 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.468 - 0.060 \cdot \lambda_{eq} (-)$$

Wall transmittance $$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

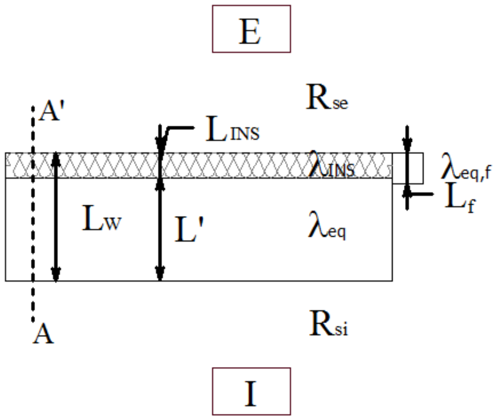
Frame transmittance $$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.47 \le U_W \le 2.09 \ \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \ \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \ \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L_W \le 0.45 \ (m)$$

3.3.21 Junction between external wall and window positioned outside

WIND.007	EXTERNAL WALL INSULATED OUTSIDE WITH WINDOW OUTSIDE
Thermal bridge characterized by the junction between an external wall insulated outside and a window positioned outside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}(f_{Rsi2} - f_{Rsi1}) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

$$\psi_1 = 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = \begin{cases} 0.04 & \text{se } L_{INS} > L_f \\ 0.168 \cdot \lambda_{eq} + 0.053 & \text{se } L_{INS} < L_f \end{cases} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi1} = 0.837 - 0.076 \cdot L' + 0.025 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.405 + 0.300 \cdot L' + 0.014 \cdot \lambda_{eq} (-)$$

Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

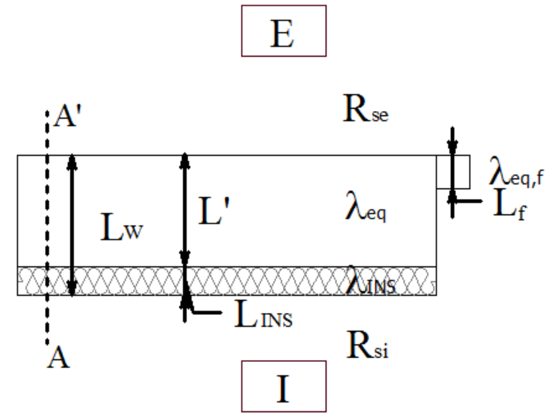
Validity field

$$1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right) \qquad 0.25 \le L' \le 0.45 \quad (m)$$

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right)$$

WIND.008 — EXTERNAL WALL INSULATED INSIDE WITH WINDOW OUTSIDE

Thermal bridge characterized by the junction between an external wall insulated inside and a window positioned outside.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = 0.227 - 0.681 \cdot U_W + 0.833 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.07 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.07 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

$$f_{Rsi1} = 0.755 - 0.029 \cdot L' - 0.335 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.444 - 0.118 \cdot \lambda_{eq} (-)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

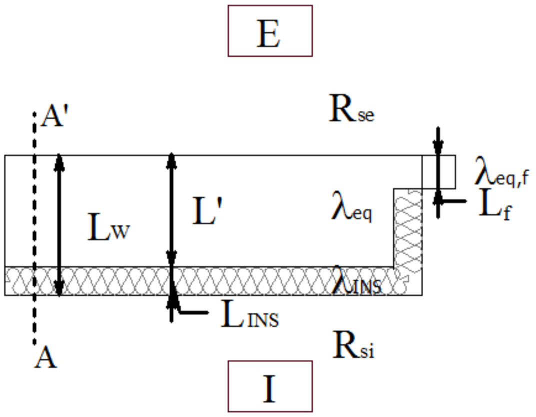
Validity field

$$0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L' \le 0.45 \ (m)$$

WIND.009 | **EXTERNAL WALL WITH FOLDING INSULATION INSIDE AND WINDOW OUTSIDE**

Thermal bridge characterized by the junction between an external wall with a folding insulation inside and a window positioned outside.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE

$$\psi_E = \psi_I = 0.103 - 0.065 \cdot U_W + 0.176 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$$

Confidence interval

$$IC_E^{95\%} = \pm 0.03 \left(\frac{W}{m \cdot K}\right)$$

$$IC_I^{95\%} = \pm 0.03 \left(\frac{W}{m \cdot K}\right)$$

TEMPERATURE FACTOR AT THE INTERNAL SURFACE

$$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$$

Confidence interval

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

With:

$$f_{Rsi1} = 0.734 - 0.025 \cdot L' - 0.226 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.492 - 0.011 \cdot L' - 0.065 \cdot \lambda_{eq} (-)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

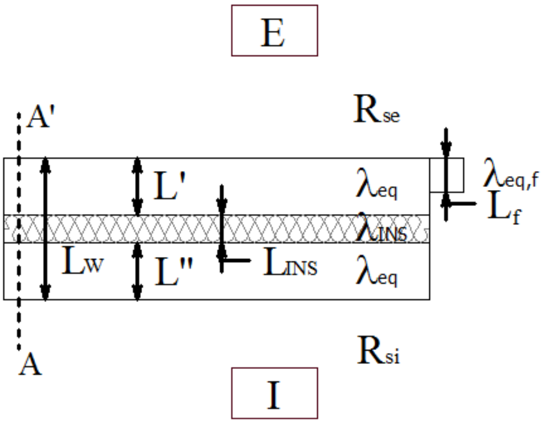
$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L' \le 0.45 \ (m)$$

<table>
<tr><td>WIND.010</td><td colspan="2">EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW OUTSIDE</td></tr>
<tr><td>Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned outside.</td><td colspan="2">



HORIZONTAL SECTION</td></tr>
<tr><td colspan="2">LINEAR THERMAL TRANSMITTANCE</td><td>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</td></tr>
<tr><td colspan="2">$\Psi_E = \Psi_I = 0.226 - 0.587 \cdot U_W + 0.497 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$</td></tr>
<tr><td colspan="2">Confidence interval

$IC_E^{95\%} = \pm 0.06 \left(\frac{W}{m \cdot K}\right)$

$IC_I^{95\%} = \pm 0.06 \left(\frac{W}{m \cdot K}\right)$</td><td>Confidence interval

$IC_{fRsi}^{95\%} = \pm 0.03 \ (-)$</td></tr>
<tr><td colspan="3">With:

$f_{Rsi1} = 0.704 + 0.093 \cdot (L' + L'') - 0.347 \cdot \lambda_{eq} (-)$

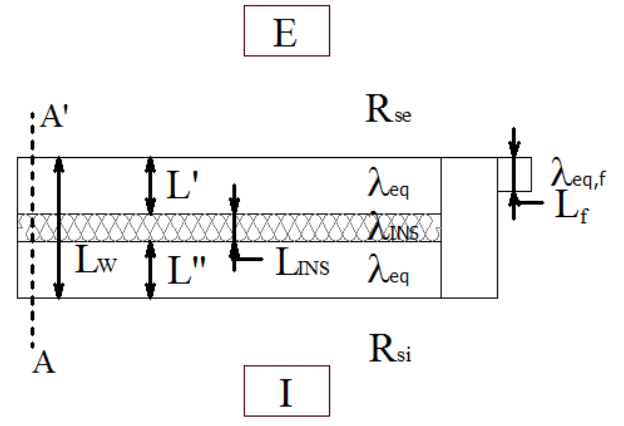
$f_{Rsi2} = 0.426 + 0.051 \cdot (L' + L'') - 0.137 \cdot \lambda_{eq} (-)$

Wall transmittance $U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$

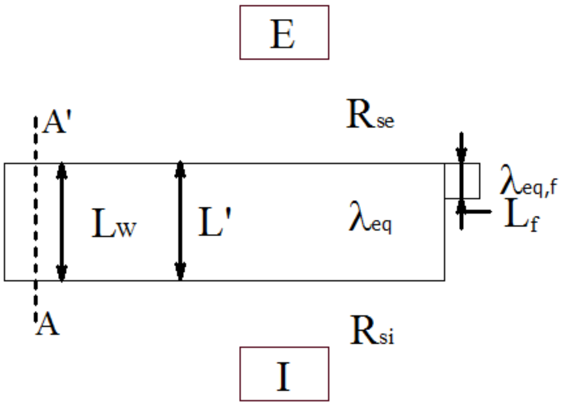
Frame transmittance $U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field

$0.17 \le U_W \le 0.58 \left(\frac{W}{m^2 \cdot K}\right)$ $1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$

$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right)$ $0.25 \le (L' + L'') \le 0.45 \ (m)$</td></tr>
</table>

<table>
<tr><th>WIND.011</th><th colspan="2">EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW OUTSIDE WITH LINTEL</th></tr>
<tr><td>Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned outside with lintel.</td><td colspan="2">

HORIZONTAL SECTION</td></tr>
<tr><td colspan="2">LINEAR THERMAL TRANSMITTANCE</td><td>TEMPERATURE FACTOR AT THE INTERNAL SURFACE</td></tr>
<tr><td colspan="2">$\psi_E = \psi_I = 1.047 - 0.094 \cdot U_W + 0.171 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$</td><td>$f_{Rsi} = 0.476 - 0.072 \cdot (L'+L") - 0.019 \cdot \lambda_{eq,f} \; (-)$</td></tr>
<tr><td colspan="2">Confidence interval
$IC_E^{95\%} = \pm 0.01 \left(\frac{W}{m \cdot K}\right)$
$IC_I^{95\%} = \pm 0.01 \left(\frac{W}{m \cdot K}\right)$</td><td>Confidence interval
$IC_{fRsi}^{95\%} = \pm 0.01 \; (-)$
.</td></tr>
<tr><td colspan="3">With:
Wall transmittance
$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L"}{\lambda_{eq}} + R_{se}} \left(\frac{W}{m^2 \cdot K}\right)$</td></tr>
<tr><td colspan="3">Validity field
$0.17 \leq U_W \leq 0.58 \left(\frac{W}{m^2 \cdot K}\right)$ $0.25 \leq (L'+L") \leq 0.45 \; (m)$
$0.23 \leq \lambda_{eq} \leq 0.81 \left(\frac{W}{m \cdot K}\right)$ $0.17 \leq \lambda_{eq,f} \leq 5.08 \left(\frac{W}{m \cdot K}\right)$</td></tr>
</table>

WIND.012	UNINSULATED EXTERNAL WALL WITH WINDOW OUTSIDE
Thermal bridge characterized by the junction between an uninsulated external wall and a window positioned outside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = -0.018 + 0.285 \cdot U_W + 1.422 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = \frac{U_f - 1.90}{3.60}\left(f_{Rsi2} - f_{Rsi1}\right) + f_{Rsi1} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.07 \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.07 \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$

With:

$$f_{Rsi1} = 0.759 - 0.072 \cdot L_W - 0.265 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.455 - 0.036 \cdot L_W - 0.096 \cdot \lambda_{eq} (-)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

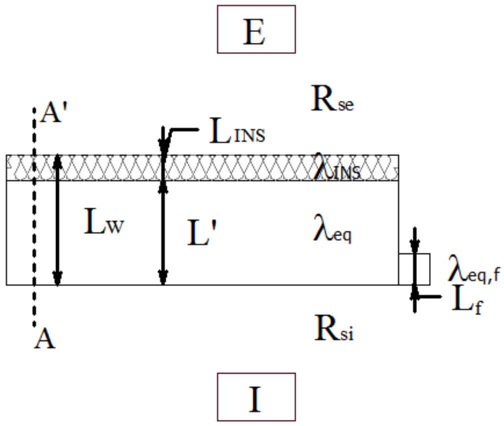
$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.47 \le U_W \le 2.09 \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L_W \le 0.45 \ (m)$$

3.3.22 Junction between external wall and window positioned inside

WIND.013	EXTERNAL WALL INSULATED OUTSIDE WITH WINDOW INSIDE
Thermal bridge characterized by the junction between an external wall insulated outside and a window positioned inside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E=\psi_I=\frac{U_f-1.90}{3.60}(\psi_2-\psi_1)+\psi_1 \quad \left(\frac{W}{m\cdot K}\right)$	$f_{Rsi}=\frac{U_f-1.90}{3.60}(f_{Rsi2}-f_{Rsi1})+f_{Rsi1}(-)$
Confidence interval $IC_E^{95\%}=\pm 0.07 \quad \left(\frac{W}{m\cdot K}\right)$ $IC_I^{95\%}=\pm 0.07 \quad \left(\frac{W}{m\cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%}=\pm 0.02 \ (-)$

With:

$$\psi_1=0.234-0.701\cdot U_W+0.914\cdot\lambda_{eq} \quad \left(\frac{W}{m\cdot K}\right)$$

$$\psi_2=0.290-0.698\cdot U_W+0.951\cdot\lambda_{eq} \quad \left(\frac{W}{m\cdot K}\right)$$

$$f_{Rsi1}=0.827-0.248\cdot\lambda_{eq}(-)$$

$$f_{Rsi2}=0.412-0.022\cdot\lambda_{eq}(-)$$

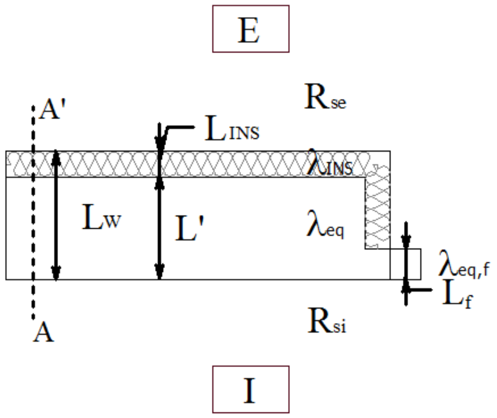
Wall transmittance $U_W=\frac{1}{R_{si}+\frac{L'}{\lambda_{eq}}+\frac{L_{INS}}{\lambda_{INS}}+R_{se}} \quad \left(\frac{W}{m^2\cdot K}\right)$

Frame transmittance $U_f=\frac{1}{R_{si}+\frac{L_f}{\lambda_{eq,f}}+R_{se}} \quad \left(\frac{W}{m^2\cdot K}\right)$

Validity field

$0.17\le U_W\le 0.58 \quad \left(\frac{W}{m^2\cdot K}\right) \quad 1.90\le U_f\le 5.50 \quad \left(\frac{W}{m^2\cdot K}\right)$

$0.23\le\lambda_{eq}\le 0.81 \quad \left(\frac{W}{m\cdot K}\right)$

WIND.014	EXTERNAL WALL WITH FOLDING INSULATION OUTSIDE AND WINDOW INSIDE
Thermal bridge characterized by the junction between an external wall with a folding insulation outside and a window positioned inside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = 0.03\left(\frac{U_f - 1.90}{3.60} + 1\right)\ \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.815 - 0.025 \cdot U_W - 0.073 \cdot \lambda_{eq,f}\ (-)$
Confidence interval $IC_E^{95\%} = \pm 0.02\ \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.02\ \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.03\ (-)$

With:

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

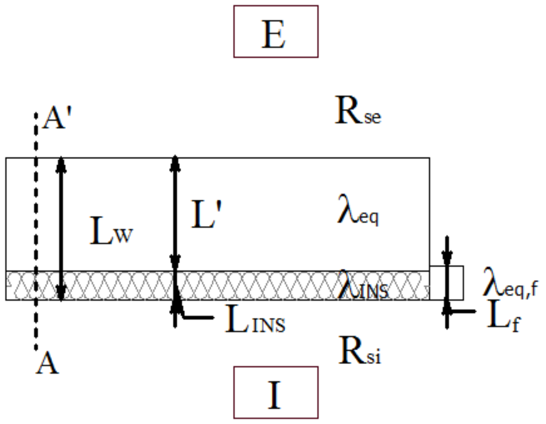
Validity field

$0.17 \leq U_W \leq 0.58\ \left(\frac{W}{m^2 \cdot K}\right)$ $1.90 \leq U_f \leq 5.50\ \left(\frac{W}{m^2 \cdot K}\right)$

$0.17 \leq \lambda_{eq,f} \leq 5.08\ \left(\frac{W}{m \cdot K}\right)$

WIND.015	EXTERNAL WALL INSULATED INSIDE WITH WINDOW INSIDE

Thermal bridge characterized by the junction between an external wall insulated inside and a window positioned outside.



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.861 - 0.046 \cdot U_W - 0.071 \cdot \lambda_{eq,f} \ (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.004 \ (-)$

With:

$$\psi_1 = 0.120 - 0.092 \cdot U_W + 0.167 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.169 - 0.105 \cdot U_W + 0.319 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

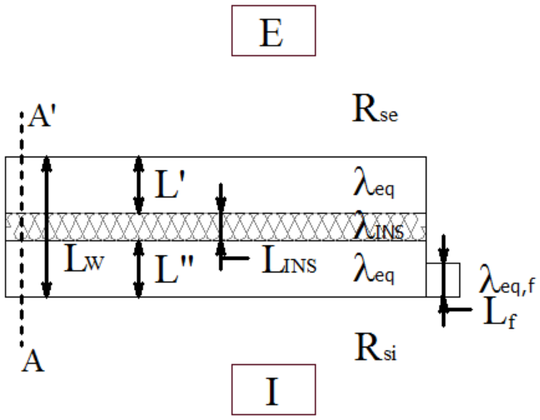
Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \quad 0.17 \le \lambda_{eq,f} \le 5.08 \quad \left(\frac{W}{m \cdot K}\right)$$

WIND.016	EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW INSIDE
Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned inside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = \frac{U_f - 1.90}{3.60}(f_{Rsi2} - f_{Rsi1}) + f_{Rsi1}(-)$
Confidence interval $IC_E^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.06 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

With:

$$\psi_1 = 0.227 - 0.598 \cdot U_W + 0.621 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.278 - 0.580 \cdot U_W + 0.668 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi1} = 0.843 - 0.054 \cdot (L' + L'') - 0.221 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.419 - 0.022 \cdot (L' + L'') - 0.011 \cdot \lambda_{eq} (-)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance

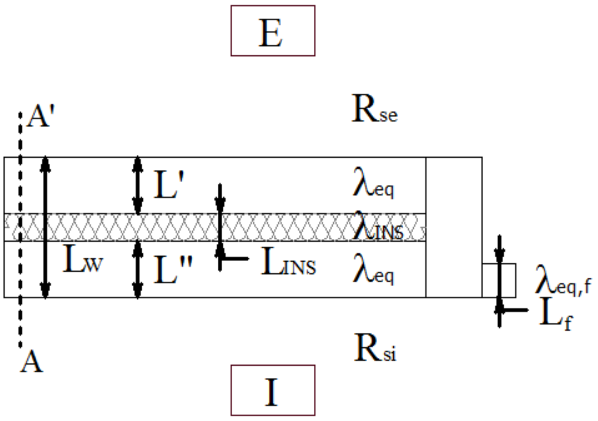
$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$$

$$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le (L' + L'') \le 0.45 \quad (m)$$

WIND.017	EXTERNAL WALL INSULATED IN THE MIDDLE WITH WINDOW INSIDE WITH LINTEL
Thermal bridge characterized by the junction between an external wall insulated in the middle and a window positioned inside with lintel.	HORIZONTAL SECTION



HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.499 - 0.027 \cdot U_W - 0.024 \cdot \lambda_{eq,f} \, (-)$
Confidence interval $IC_E^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$

With:

$$\psi_1 = 0.928 - 0.293 \cdot U_W + 0.311 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.988 - 0.293 \cdot U_W + 0.311 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

Wall transmittance

$$U_W = \frac{1}{R_{si} + \frac{L'}{\lambda_{eq}} + \frac{L_{INS}}{\lambda_{INS}} + \frac{L''}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

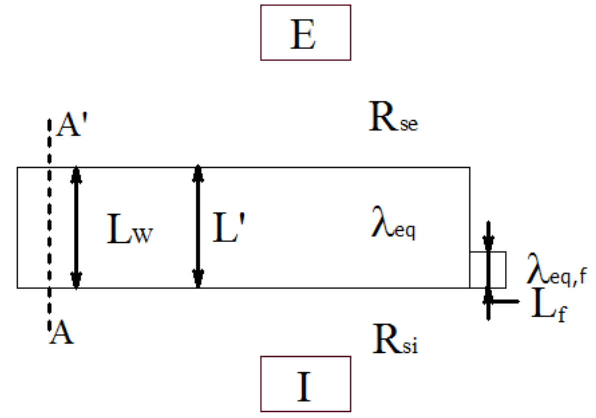
Frame transmittance

$$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$0.17 \le U_W \le 0.58 \quad \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$

$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \quad 0.17 \le \lambda_{eq,f} \le 5.08 \quad \left(\frac{W}{m \cdot K}\right)$

WIND.018	UNINSULATED EXTERNAL WALL WITH WINDOW INSIDE
Thermal bridge characterized by the junction between an uninsulated external wall and a window positioned inside.	 HORIZONTAL SECTION

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_E = \psi_I = \frac{U_f - 1.90}{3.60}(\psi_2 - \psi_1) + \psi_1 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = \frac{U_f - 1.90}{3.60}(f_{Rsi2} - f_{Rsi1}) + f_{Rsi1} (-)$
Confidence interval $IC_E^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.05 \quad \left(\frac{W}{m \cdot K}\right)$	Confidence interval $IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$

With:

$$\psi_1 = 0.211 - 0.229 \cdot U_W + 0.645 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$\psi_2 = 0.141 - 0.229 \cdot U_W + 0.645 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi1} = 0.812 + 0.055 \cdot L_W - 0.283 \cdot \lambda_{eq} (-)$$

$$f_{Rsi2} = 0.406 + 0.023 \cdot L_W - 0.037 \cdot \lambda_{eq} (-)$$

Wall transmittance $$U_W = \frac{1}{R_{si} + \frac{L_W}{\lambda_{eq}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Frame transmittance $$U_f = \frac{1}{R_{si} + \frac{L_f}{\lambda_{eq,f}} + R_{se}} \quad \left(\frac{W}{m^2 \cdot K}\right)$$

Validity field

$0.47 \le U_W \le 2.09 \quad \left(\frac{W}{m^2 \cdot K}\right) \quad 1.90 \le U_f \le 5.50 \quad \left(\frac{W}{m^2 \cdot K}\right)$

$0.23 \le \lambda_{eq} \le 0.81 \quad \left(\frac{W}{m \cdot K}\right) \quad 0.25 \le L_W \le 0.45 \quad (m)$

3.4 FINAL EVALUATION ABOUT CONDENSATION

After having developed the correlations for each type of thermal bridge schematization, $f_{Rsi,min}$ values have been compared with each other to do some evaluation.

For this scope it is important to remember that the minimum acceptable temperature factor at the internal surface is:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} = \frac{14.3 - (-5)}{20 - (-5)} = 0.77 \quad (-)$$

Junction between external wall and un-insulated pillar

The considerations about these cases are the following:

- PIL.001 and PIL.003: the results show that with the brick density decrease the condensation increases: this is because the brick density decrease generates a greater gap between the wall thermal transmittance and that one of the pillar. So the heat flow rate increases with the linear thermal transmittance and the internal surface temperature decreases. This aspect is more visible with a greater pillar length S_P.
- PIL.002 and PIL.004: they always condense because the pillar creates a preferential passage for the heat flow. This is so big that it determines a surface temperature lower than that one of the dew point and thus the condensation.

Junction between external wall and insulated pillar

The considerations about these cases are the following ones:

- PIL.005, PIL.007 and PIL.008: they never condense.
- PIL.006: it condenses only with a medium (1200 kg/m^3) or high (1800 kg/m^3) brick density and with a wall characterized by a thermal transmittance equal to the maximum one. These properties cause a surface temperature less than that one of the dew point with a consequent condensation.

After an examination of these evaluations about junction between external wall and pillar, it is possible to see that when the pillar isn't insulated the condensation is very likely; in fact the cases with an insulated pillar hardly ever condense.

Concave corner with un-insulated pillar

The considerations about these cases are the following:

- CC.001: it condenses only with a medium (1200 kg/m^3) or high (1800 kg/m^3) brick density and with a wall characterized by a thermal transmittance equal to the maximum one. This case is worse than CC.002 and CC.003 because a corner with a wall insulated inside determines a greater passage of the heat flow than a corner with a wall insulated outside or in the middle (**Figure 3.2**). Whereas it is worse than the case without insulation (CC.004) because the presence of the insulation generates a greater difference between the wall thermal transmittance and that one of the pillar and thus an heat flow increase.

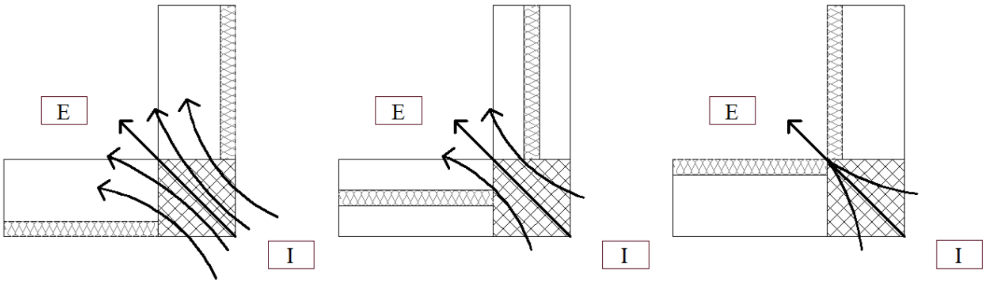


Figure 3.2 - Heat flow rate in concave corners with three different type of insulated wall

- CC.002 and CC.003: they never condense.
- CC.004: this case condenses only with an high brick density (1800 kg/m^3) and with a wall characterized by a thermal transmittance equal to the maximum one. These properties cause a surface temperature less than that one of the dew point with a consequent condensation.

Concave corner with insulated pillar

These cases (CC.005, CC.006 and CC.007) never condense.

Concave corner without pillar

The considerations about these cases are the following:

- CC.008, CC.009 and CC.010: they never condense.
- CC.011: the situation is very similar to CC.004 case, in fact both don't present any kind of insulation.

Projecting corner with un-insulated pillar

These cases (PC.001, PC.002, PC.003 and PC.004) always condense because the pillar creates a preferential passage for the heat flow. This is so big that it determines a surface temperature less than that one of the dew point and so the condensation.

Projecting corner with insulated pillar

The considerations about these cases are the following:

- PC.005: the results show that with the brick density decrease the condensation increases in fact this case condense only with a low brick density (760 kg/m^3) and with a wall characterized by a thermal transmittance equal to the maximum one; this is because the brick density decrease generates a greater gap between the wall thermal transmittance and that one of the pillar. So the heat flow rate increases with the linear thermal transmittance and the internal surface temperature decreases.
- PC.006: it always condenses, except for the cases with a low brick density (760 kg/m^3) and an insulation thickness equal to 10 cm or 15 cm (U_m, U_{min}, U_u and U_y). These properties decrease the heat flow rate with an increase of the internal surface temperature.
- PC.007: it always condenses, except for the cases with an insulation thickness equal to 15 cm (U_{min} and U_y). As said before, these properties decrease the heat flow rate with an increase of the internal surface temperature.

Projecting corner without pillar

The considerations about these cases are the following:

- PC.008, PC.009 and PC.010: they never condense.
- PC.011: it always condenses, except for the cases with a low brick density (760 kg/m^3). These properties decrease the heat flow rate with an increase of the internal surface temperature.

Comparison between concave and projecting corners

From a comparison between the two types of corner studied it is possible to see that concave corners are better than the projecting ones.

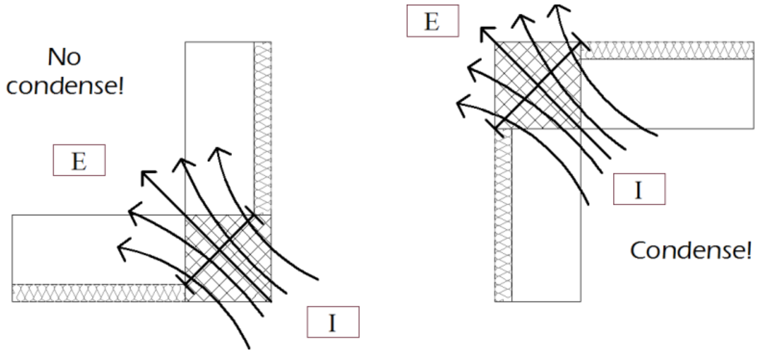


Figure 3.3 - Comparison between concave and projecting corners

In this picture, which compares the worst cases of both types of corner, it is possible to see that in the first one the passage width is less than in the second one.

Another important evaluation is that in the concave and the projecting corners the presence of the pillar increases a lot the possibility of condensation, in fact the cases without pillar hardly ever condense.

Junction between external wall and un-insulated plane roof with un-insulated beam

These cases (PR.001, PR.002, PR.003 and PR.004) always condense because the beam creates a preferential passage for the heat flow. This is so big that it determines a surface temperature less than that one of the dew point and thus the condensation.

Junction between external wall and insulated plane roof with un-insulated beam

These cases (PR.005, PR.006, PR.007 and PR.008) always condense, except for PR.005, which doesn't condense only in the cases of medium brick density (1200 kg/m^3) and a wall characterized by a thermal transmittance equal to the minimum one or of high brick density (1800 kg/m^3) and a wall characterized by a thermal transmittance equal to the medium or the minimum one. This happens because the insulation increases the difference between the thermal transmittance of the building elements composing the junction and that one of the beam and so junctions with a low brick density become more prone to condensation than the same with a high brick density.

Junction between external wall and insulated plane roof with insulated beam

When also the beam is insulated (PR.009) there isn't condensation.

Junction between external wall and un-insulated plane roof with parapet

These cases (PR.010, PR.011, PR.012, PR.013 and PR.014) always condense for the same reasons of the cases with un-insulated plane roof and un-insulated beam (PR.001, PR.002, PR.003 and PR.004).

Junction between external wall and insulated plane roof with parapet

The considerations about these cases are the following:

- PR.015 and PR.018: they never condense because they have an insulated beam.
- PR.016 and PR.017: they always condense because the beam isn't insulated and create a preferential passage for the heat flow.

From all the evaluation for junction between external wall and plane roof, it is possible to say that to avoid condensation the beam has to be insulated.

Junction between external wall and floor with un-insulated beam

The considerations about these cases are the following:

- FL.001: owing to the difference between the wall thermal transmittance and that one of the beam, this case condenses only in case of a medium (1200 kg/m^3) or a low (760 kg/m^3) brick densities with a wall characterized by a thermal transmittance equal to the maximum one. These properties cause a surface temperature less than that one of the dew point with a consequent condensation.
- FL.002: it always condenses because the beam creates a preferential passage for the heat flow. This is so big that it determines a surface temperature less than that one of the dew point and so the condensation.
- FL.003: it condenses only with wall characterized by a thermal transmittance equal to the maximum one.
- FL.004: it always condenses when the beam length is equal to 50 cm. When the beam length is equal to 60 cm it doesn't condense only in the cases with a low (760 kg/m^3) and a medium (1200 kg/m^3) brick densities and a wall characterized by a thermal transmittance equal to the minimum one; whereas when it is equal to 70 cm it doesn't condense only in cases with a medium brick density (1200 kg/m^3) and a wall characterized by a thermal transmittance equal to the minimum one or cases with a low brick density (760 kg/m^3) and a wall characterized by a thermal transmittance equal to the medium or the minimum one. In this case seems that the decrease of the beam width generates a greater difference between the wall thermal transmittance and that one of the beam. So the heat flow increases and the internal surface temperature decreases.

Junction between external wall and floor with insulated beam

These cases (FL.005, FL.006 and FL.007) never condense, except for FL.006, which condenses in cases of a medium brick density (1200 kg/m^3) and a wall characterized by a thermal transmittance equal to the maximum one or cases of a maximum brick density (1800 kg/m^3) and a wall characterized by a thermal transmittance equal to the medium or the maximum one.

From all the evaluation for junction between external wall and floor, it is possible to say that: when the beam isn't insulated the condensation is more likely than the cases with insulated beam. The exception is FL.006, that with an internal insulation can't nullify the thermal bridge effect.

Junction between external and internal walls

These cases (INT.001, INT.002, INT.003 and INT.004) never condense, except for INT.004, which condenses in cases with an high brick density (1800 kg/m^3) and a wall characterized by a thermal transmittance equal to the maximum one. These properties cause a surface temperature less than that one of the dew point with a consequent condensation.

So superficial condensation happens only when the wall isn't insulated.

Junction between external wall and floor with un-insulated balcony

The considerations about these cases are the following:

- BALC.001: owing to the difference between the wall thermal transmittance and that of the balcony, this case condenses only in case of a low brick density (760 kg/m^3) with a wall characterized by a thermal transmittance equal to the maximum one. If the floor thickness increases it condenses also in the cases of a medium brick density (1200 kg/m^3) with a wall characterized by a thermal transmittance equal to the maximum one. These properties cause a surface temperature less than that one of the dew point with a consequent condensation.
- BALC.002: it always condenses, except for cases of a low brick density (760 kg/m^3) with a wall characterized by a thermal transmittance equal to the medium or minimum one. These properties decrease the heat flow rate with an increase of the surface temperature.
- BALC.003: it condenses only in cases of wall characterized by a thermal transmittance equal to the maximum one.
- BALC.004: it condenses only in cases of wall characterized by a thermal transmittance equal to the maximum one and also in cases of an high brick density (1800 kg/m^3) and a wall characterized by a thermal transmittance equal to the medium one.

Junction between external wall and floor with insulated balcony

These cases (BALC.005, BALC.006 and BALC.007) never condense, because the balcony is insulated.

What has been said before for junction between external wall and floor can be extended to balcony: when the balcony is insulated the condensation doesn't occur, in the other cases it is very likely.

Junction between external wall and window positioned in the middle

The metallic frames always determine condensation because of the difference between the frame thermal transmittance and that one of the wall. The wooden ones act in the same way, except for the cases with the insulation in correspondence of the window (WIND.004), which never condense, and for the cases with insulation outside (WIND.001), which don't condense only in cases of a low brick density (760 kg/m^3) and a wall characterized by a thermal transmittance equal to the maximum one. These properties decrease the heat flow rate with an increase of the internal surface temperature.

Junction between external wall and window positioned outside

The metallic frames, as said before, always determine condensation because of the difference between the frame thermal transmittance and that one of the wall. The wooden ones act in the same way, except for the cases with the insulation in correspondence of the window (WIND.007), which never condense.

Junction between external wall and window positioned inside

The metallic frames, as said before, always determine condensation. For the wooden ones the considerations are the following:

- WIND.013 and WIND.016: they don't condense only in cases with a low brick density (760 kg/m^3). These properties decrease the heat flow rate with an increase of the surface temperature.
- WIND.014 and WIND.015: they never condense.
- WIND.017: it always condenses because of the presence of an architrave between the wall and the window.
- WIND.018: it doesn't condense only in cases with a low brick density (760 kg/m^3) and a wall characterized by a thermal transmittance equal to the medium or the minimum one.

Windows comparison

It is possible to say that the best condition is offered by windows positioned inside because the passage of the heat flow is reduced compared to the other two positions.

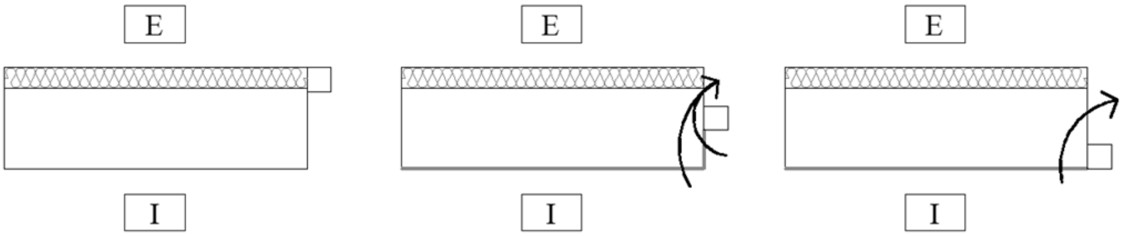


Figure 3.4 - Windows comparison

The **Figure 3.4** shows that the alignment of window and insulation reduces almost totally the thermal bridge. Whereas for the cases with a window positioned in the middle and a window positioned inside with an insulation outside of the wall the thermal bridge becomes significant. From the figure it is possible to see that the input length in the case of a window positioned in the middle is greater than the case of a window positioned inside and the heat flow increase.

4 VALIDATION

4.1 ADOPTED APPROACH

After having developed the correlations about the linear thermal transmittance and the temperature factor at the internal surface, it has been decided to evaluate if these ones could be applied on real examples.

For this purpose, it has been necessary to execute some simulations on real building junctions that correspond to the reference ones.

FLUENT is a very precise program, which allows to define all material properties, the boundary conditions and the precision level of the geometric mesh; but this software is expensive and it requires a lot of time to learn it and its preprocessors, such as GAMBIT. In order to verify if the correlations can be applied to real examples studied by mid-level planners, it has been decided to use a free software, which is very easy to learn and to use: this is the case of THERM. An important difference between these two programs is the geometric model: FLUENT is based on finite volume calculation and it allows to define precisely the amplitude of the mesh, whereas THERM is based on finite element calculation and it provides the mesh automatically (it is possible to impose only a level of definition of it).

The results of the simulation through THERM are the minimum temperature at the internal surface and the medium thermal transmittance of any building junction.

The first one allows to determine the minimum acceptable value of the temperature factor at the internal surface for any case, through the following rule ***(2.26)***:

$$f_{Rsi,min} = \frac{T_{si,min} - T_e}{T_i - T_e} \quad (-)$$

The second one allows to calculate the heat flow rate due to the thermal bridge:

$$Q_{TB} = U_{av} \cdot A \cdot (T_i - T_e) \quad (W) \qquad \textbf{(4.1)}$$

With: $A = l_{TB} \cdot z_{TB}$

Where:

- U_{av} is the medium thermal transmittance of the building junction;
- T_i and T_e are the internal and external air temperatures;
- A is the total surface of the building junction;
- z_{TB} is the thermal bridge development;
- l_{TB} is the other dimension of the thermal bridge.

As said before, the linear thermal transmittance derives from the difference between this heat flow rate and the one-dimensional one. According to***(2.1)*** and ***(2.3)***, it is possible to obtain:

$$\Psi = \frac{(Q_{TB} - Q_{1D})}{\Delta T \cdot z_{TB}} = \frac{A \cdot (T_i - T_e) \cdot (U_{av} - U_W)}{(T_i - T_e) \cdot z_{TB}} = l_{TB} \cdot (U_{av} - U_W) \quad (\frac{W}{m \cdot K}) \qquad \textbf{(4.2)}$$

In case of two different dispersant building elements (e.g. external wall and roof), it becomes:

$$\Psi = \frac{(Q_{TB} - Q_{1D})}{\Delta T \cdot z_{TB}} = \frac{(T_i - T_e) \cdot \left(A \cdot U_{av} - A_W \cdot U_W - A_{roof} \cdot U_{roof}\right)}{(T_i - T_e) \cdot z_{TB}} \tag{4.3}$$

$$= l_{TB} \cdot U_{av} + l_W \cdot U_W + l_{roof} \cdot U_{roof} \quad \left(\frac{W}{m \cdot K}\right)$$

With: $A = A_W + A_{roof} = l_W \cdot z_{TB} + l_{roof} \cdot z_{TB}$

Where:

- U_W and U_{roof} are the wall and roof (or other opaque elements) thermal transmittance;
- A_W and A_{roof} are the wall and roof (or other opaque elements) total surface;
- l_W and l_{roof} are the wall and roof (or other opaque elements) extension.

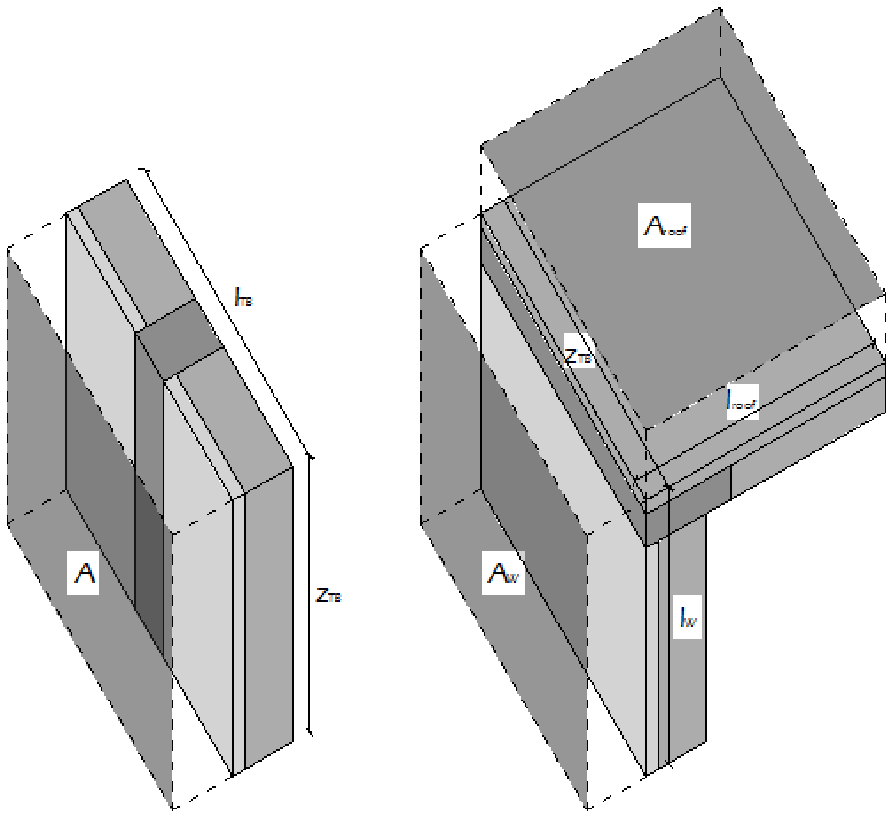


Figure 4.1 - Schematization of the thermal bridge dimensions

In order to execute the validation, it has been decided to execute simulation based on internal dimensions only on representative families of thermal bridges, which are the following:

- junctions between external wall and pillar;
- projecting corners;
- junctions between external wall and floor.

The number of real examples studied for each schematization of thermal bridge is five. The first cases of the first two families have been analyzed through nine examples also, but in ANNEX E (chapter **6.5**) it is shown that the difference is negligible.

The approach used in these simulations is the same of that of a mid-level planner, in fact the materials used in the stratigraphies have been taken from constructive details of some projects, technique reports and reference norms (such as the UNI EN ISO 10355 [N13]).

The results obtained by the simulations on real building junctions are new points near the plane described by each reference correlation. So it has been possible to evaluate the mean square error (MSE) given by these points.

The mean square error (MSE) is one of many ways to quantify the difference between values implied by an estimator and the true values of the quantity being estimated.

For example, the mean square error for the linear thermal transmittance is:

$$MSE_{\Psi} = \sqrt{\frac{\sum_{i=1}^{N}\left(\Psi_i - \widehat{\Psi}_i\right)^2}{N-1}} \qquad (4.4)$$

Where:

- $\Psi_i$is the true value of the quantity being estimated;
- $\widehat{\Psi}_i$ is the value obtained through the estimator (the correlation);
- N is the number of samples studied (in this case five).

Finally, as a reference parameter, it has been indicated its percentage on the average of the values obtained through the simulations on real examples (MSEP).

$$MSEP_{\Psi} = \frac{MSE_{\Psi}}{\sum \frac{\Psi_i}{N}} \qquad (4.5)$$

According to the its definition, the mean square error is positive, but in the validation reports it has been decided to point out its sign with reference to the values of the obtained error. When only one error has a different sign and an order of magnitude smaller than the other ones, this value is considered as an outlayer and so the final sign is determined by the other ones.

4.2 PROGRAMS COMPARISON

The values of linear thermal transmittance and temperature factor at the internal surface used to determine the reference abacus correlations have been obtain through FLUENT. Whereas, as said before, the simulations done on real building junctions to validate these correlations have been developed through THERM.

At the beginning it has been necessary to compare the results of the same simulations obtained through the two programs to evaluate the relative error of one program on the other. For this purpose, it has been taken into consideration the junction between external wall and pillar with a pillar width equal to 30 cm.

The following table resumes the value obtained through both programs, with:

$$\Delta U = U_{av} - U_W \quad (\frac{W}{m^2 \cdot K}) \qquad \textit{(4.6)}$$

$$\Delta Q = |Q_{TH} - Q_{FL}| \quad (W) \qquad \textit{(4.7)}$$

$$\Delta \Psi = |\Psi_{TH} - \Psi_{FL}| \quad (\frac{W}{m \cdot K}) \qquad \textit{(4.8)}$$

$$\Delta f_{Rsi,min} = \left|f_{Rsi,min,TH} - f_{Rsi,min,FL}\right| \quad (-) \qquad \textit{(4.9)}$$

$$f_{Rsi,min,TH} = \frac{T_{si,min,TH} - T_e}{T_i - T_e} \quad (-) \qquad \textit{(4.10)}$$

$$\Delta T_{si,min} = \left|T_{si,min,TH} - T_{si,min,FL}\right| \quad (°C) \qquad \textit{(4.11)}$$

$$T_{si,min,FL} = f_{Rsi,min,FL} \cdot (T_i - T_e) + T_e \quad (-) \qquad \textit{(4.12)}$$

Where:

- U_{av} is the medium thermal transmittance due to the thermal bridge;
- U_W is the wall thermal transmittance;
- Q_{TH} is the heat flow rate determined through THERM, using *(4.1)* with z_{TB}=1m;
- Q_{FL} is the heat flow rate determined through FLUENT;
- Ψ_{TH} is the linear thermal transmittance determined through U_{av} by THERM, using *(4.2)*;
- Ψ_{FL} is the heat flow rate determined through FLUENT;
- $T_{si,min,TH}$ is the minimum temperature at the internal surface determined through THERM;
- $f_{Rsi,min,TH}$ is the minimum acceptable value of the temperature factor at the internal surface determined through THERM, using *(4.10)* with the design hypothesis of T_i=20°C and T_e=-5°C;
- $f_{Rsi,min,FL}$ is the minimum acceptable value of the temperature factor at the internal surface determined through FLUENT;
- $T_{si,min,FL}$ is the minimum temperature at the internal surface determined through FLUENT, using *(4.12)*.

	Brick density	U_W type	U_W	U_{av}	ΔU	l_{TB}	Q_{TH}	Q_{FL}	ΔQ	$\Delta Q/Q_{FL}$	Ψ_{TH}	Ψ_{FL}	$\Delta\Psi$	$\Delta\Psi/\Psi_{FL}$	$T_{si,min,TH}$	$f_{Rsi,min,TH}$	$f_{Rsi,min,FL}$	$\Delta f_{Rsi,min}$	$\Delta f_{Rsi,min}/f_{Rsi,min,FL}$	$T_{si,min,FL}$	$\Delta T_{si,min}$	$\Delta T_{si,min}/T_{si,min,FL}$
	(kg/m^3)		(W/m^{2}K)	(W/m^{2}K)	(W/m^{2}K)	(m)	(W)	(W)	(W)	%	(W/mK)	(W/mK)	(W/mK)	%	(°C)	(-)	(-)	(-)	%	(°C)	(°C)	%
PIL.001	1200	U_{max}	0,531	0,949	0,418	2,3	54,57	54,47	0,10	0,19	0,962	0,957	0,004	0,42	11,80	0,672	0,673	0,001	0,22	11,84	0,04	0,31
		U_m	0,293	0,644	0,351	2,3	37,04	36,98	0,06	0,17	0,807	0,805	0,003	0,31	14,50	0,780	0,779	0,001	0,09	14,48	0,02	0,12
		U_{min}	0,210	0,537	0,327	2,3	30,89	30,84	0,05	0,16	0,752	0,750	0,002	0,27	15,30	0,812	0,814	0,002	0,25	15,35	0,05	0,33
	1800	U_{max}	0,578	1,025	0,447	2,3	58,94	58,82	0,13	0,21	1,027	1,022	0,005	0,49	12,20	0,688	0,689	0,001	0,15	12,23	0,03	0,21
		U_m	0,316	0,701	0,385	2,3	40,32	40,24	0,08	0,20	0,886	0,883	0,003	0,36	14,90	0,796	0,796	0,000	0,03	14,89	0,01	0,04
		U_{min}	0,223	0,583	0,359	2,3	33,51	33,45	0,06	0,19	0,827	0,824	0,003	0,31	15,70	0,828	0,830	0,002	0,28	15,76	0,06	0,37
	760	U_{max}	0,399	0,787	0,388	2,3	45,25	45,16	0,09	0,21	0,893	0,889	0,004	0,43	11,10	0,644	0,645	0,001	0,15	11,12	0,02	0,22
		U_m	0,227	0,536	0,309	2,3	30,81	30,75	0,05	0,17	0,711	0,708	0,002	0,30	13,70	0,748	0,747	0,001	0,08	13,69	0,01	0,11
		U_{min}	0,170	0,453	0,283	2,3	26,06	26,02	0,04	0,16	0,651	0,649	0,002	0,26	14,50	0,780	0,782	0,002	0,20	14,54	0,04	0,28
PIL.002	1200	U_{max}	0,531	0,888	0,357	2,3	51,08	50,92	0,16	0,32	0,822	0,815	0,007	0,80	9,40	0,576	0,572	0,004	0,71	9,30	0,10	1,09
		U_m	0,293	0,594	0,301	2,3	34,15	34,01	0,13	0,39	0,691	0,686	0,005	0,77	11,50	0,660	0,659	0,001	0,20	11,47	0,03	0,29
		U_{min}	0,210	0,492	0,282	2,3	28,30	28,21	0,08	0,30	0,648	0,645	0,003	0,52	12,30	0,692	0,690	0,002	0,25	12,26	0,04	0,35
	1800	U_{max}	0,578	0,946	0,367	2,3	54,38	54,20	0,18	0,34	0,845	0,837	0,007	0,87	8,90	0,556	0,552	0,004	0,71	8,80	0,10	1,11
		U_m	0,316	0,635	0,319	2,3	36,50	36,35	0,16	0,43	0,733	0,727	0,006	0,86	11,00	0,640	0,637	0,003	0,44	10,93	0,07	0,64
		U_{min}	0,223	0,524	0,301	2,3	30,14	30,04	0,10	0,33	0,692	0,688	0,004	0,57	11,80	0,672	0,670	0,002	0,29	11,75	0,05	0,41
	760	U_{max}	0,399	0,757	0,358	2,3	43,53	43,38	0,15	0,35	0,824	0,818	0,006	0,74	10,00	0,600	0,598	0,002	0,37	9,94	0,06	0,55
		U_m	0,227	0,511	0,285	2,3	29,40	29,30	0,10	0,35	0,654	0,650	0,004	0,63	12,30	0,692	0,690	0,002	0,32	12,25	0,05	0,45
		U_{min}	0,170	0,431	0,261	2,3	24,77	24,70	0,07	0,29	0,599	0,596	0,003	0,47	13,10	0,724	0,721	0,003	0,44	13,02	0,08	0,61
PIL.003	1200	U_{max}	0,531	0,936	0,405	2,3	53,83	53,85	0,02	0,04	0,932	0,932	0,001	0,09	11,10	0,644	0,644	0,000	0,07	11,11	0,01	0,10
		U_m	0,293	0,627	0,334	2,3	36,05	36,03	0,02	0,06	0,768	0,767	0,001	0,11	13,80	0,752	0,752	0,000	0,05	13,81	0,01	0,07
		U_{min}	0,210	0,519	0,309	2,3	29,84	29,82	0,02	0,06	0,710	0,709	0,001	0,10	14,70	0,788	0,788	0,000	0,01	14,70	0,00	0,01
	1800	U_{max}	0,578	1,004	0,425	2,3	57,71	57,73	0,02	0,03	0,978	0,979	0,001	0,08	11,30	0,652	0,651	0,001	0,23	11,26	0,04	0,33
		U_m	0,316	0,674	0,358	2,3	38,78	38,75	0,03	0,08	0,824	0,823	0,001	0,15	14,00	0,760	0,761	0,001	0,15	14,03	0,03	0,21
		U_{min}	0,223	0,556	0,333	2,3	31,97	31,94	0,03	0,08	0,765	0,764	0,001	0,13	14,90	0,796	0,798	0,002	0,20	14,94	0,04	0,27
	760	U_{max}	0,399	0,785	0,386	2,3	45,13	45,10	0,03	0,06	0,888	0,887	0,001	0,13	10,80	0,632	0,632	0,000	0,02	10,80	0,00	0,03
		U_m	0,227	0,532	0,305	2,3	30,58	30,55	0,03	0,10	0,701	0,700	0,001	0,17	13,40	0,736	0,735	0,001	0,17	13,37	0,03	0,23
		U_{min}	0,170	0,448	0,278	2,3	25,76	25,73	0,02	0,09	0,639	0,638	0,001	0,15	14,20	0,768	0,769	0,001	0,09	14,22	0,02	0,13

	Brick density	U_W type	U_W	U_{av}	ΔU	l_{TB}	Q_{TH}	Q_{FL}	ΔQ	$\Delta Q/Q_{FL}$	Ψ_{TH}	Ψ_{FL}	$\Delta\Psi$	$\Delta\Psi/\Psi_{FL}$	$T_{si,min,TH}$	$f_{Rsi,min,TH}$	$f_{Rsi,min,FL}$	$\Delta f_{Rsi,min}$	$\Delta f_{Rsi,min}/f_{Rsi,min,FL}$	$T_{si,min,FL}$	$\Delta T_{si,min}$	$\Delta T_{si,min}/T_{si,min,FL}$
	(kg/m^3)		(W/m^{2}K)	(W/m^{2}K)	(W/m^{2}K)	(m)	(W)	(W)	(W)	%	(W/mK)	(W/mK)	(W/mK)	%	(°C)	(-)	(-)	(-)	%	(°C)	(°C)	%
PIL.004	1200	U_{max}	1,580	1,824	0,244	2,3	104,90	104,91	0,01	0,00	0,562	0,563	0,000	0,04	9,80	0,592	0,593	0,001	0,13	9,82	0,02	0,20
		U_m	1,098	1,313	0,215	2,3	75,51	75,51	0,00	0,00	0,495	0,495	0,000	0,01	12,20	0,688	0,689	0,001	0,19	12,23	0,03	0,27
		U_{min}	0,997	1,202	0,205	2,3	69,11	69,11	0,00	0,00	0,472	0,472	0,000	0,01	12,80	0,712	0,713	0,001	0,08	12,81	0,01	0,11
	1800	U_{max}	2,089	2,260	0,171	2,3	129,97	130,01	0,04	0,03	0,394	0,395	0,001	0,38	9,70	0,588	0,589	0,001	0,17	9,73	0,03	0,26
		U_m	1,506	1,663	0,157	2,3	95,62	95,64	0,02	0,02	0,360	0,361	0,001	0,21	12,10	0,684	0,685	0,001	0,17	12,13	0,03	0,24
		U_{min}	1,378	1,529	0,151	2,3	87,91	87,93	0,02	0,02	0,346	0,347	0,001	0,19	12,70	0,708	0,708	0,000	0,05	12,71	0,01	0,07
	760	U_{max}	0,796	1,149	0,353	2,3	66,05	65,99	0,06	0,09	0,812	0,810	0,002	0,30	9,80	0,592	0,591	0,001	0,10	9,79	0,01	0,15
		U_m	0,524	0,818	0,294	2,3	47,01	46,97	0,04	0,08	0,676	0,674	0,001	0,22	12,20	0,688	0,686	0,002	0,25	12,16	0,04	0,35
		U_{min}	0,470	0,747	0,277	2,3	42,97	42,93	0,03	0,08	0,637	0,636	0,001	0,20	12,70	0,708	0,709	0,001	0,17	12,73	0,03	0,24
PIL.005	1200	U_{max}	0,531	0,707	0,176	2,3	40,67	40,51	0,16	0,40	0,405	0,399	0,006	1,62	14,90	0,796	0,798	0,002	0,29	14,96	0,06	0,39
		U_m	0,293	0,461	0,168	2,3	26,50	26,37	0,13	0,49	0,386	0,381	0,005	1,35	16,20	0,848	0,849	0,001	0,13	16,23	0,03	0,17
		U_{min}	0,210	0,360	0,149	2,3	20,68	20,56	0,12	0,59	0,343	0,339	0,005	1,42	16,90	0,876	0,877	0,001	0,14	16,93	0,03	0,18
		U_x	0,210	0,424	0,214	2,3	24,39	24,29	0,10	0,41	0,492	0,488	0,004	0,82	16,00	0,840	0,841	0,001	0,09	16,02	0,02	0,12
		U_y	0,531	0,516	-0,015	2,3	29,69	29,64	0,04	0,15	-0,034	-0,036	0,002	4,91	18,20	0,928	0,928	0,000	0,05	18,21	0,01	0,07
	1800	U_{max}	0,578	0,796	0,217	2,3	45,74	45,58	0,16	0,35	0,499	0,493	0,006	1,29	14,40	0,776	0,780	0,004	0,51	14,50	0,10	0,69
		U_m	0,316	0,529	0,213	2,3	30,41	30,27	0,14	0,45	0,489	0,484	0,005	1,12	15,90	0,836	0,837	0,001	0,11	15,92	0,02	0,14
		U_{min}	0,223	0,415	0,192	2,3	23,88	23,75	0,13	0,56	0,441	0,436	0,005	1,21	16,70	0,868	0,867	0,001	0,07	16,69	0,01	0,09
		U_x	0,223	0,477	0,254	2,3	27,45	27,36	0,09	0,34	0,584	0,580	0,004	0,65	15,90	0,836	0,836	0,000	0,03	15,91	0,01	0,04
		U_y	0,578	0,560	-0,019	2,3	32,19	32,14	0,05	0,16	-0,043	-0,045	0,002	4,47	18,20	0,928	0,923	0,005	0,55	18,07	0,13	0,70
	760	U_{max}	0,399	0,516	0,117	2,3	29,67	29,53	0,14	0,48	0,269	0,264	0,006	2,16	15,90	0,836	0,839	0,003	0,38	15,98	0,08	0,49
		U_m	0,227	0,326	0,099	2,3	18,76	18,66	0,10	0,53	0,229	0,225	0,004	1,77	17,00	0,880	0,881	0,001	0,07	17,02	0,02	0,09
		U_{min}	0,170	0,254	0,084	2,3	14,61	14,53	0,08	0,57	0,193	0,190	0,003	1,75	17,60	0,904	0,903	0,001	0,10	17,58	0,02	0,13
		U_x	0,170	0,317	0,147	2,3	18,26	18,15	0,10	0,57	0,339	0,335	0,004	1,23	16,50	0,860	0,859	0,001	0,12	16,48	0,02	0,15
		U_y	0,399	0,396	-0,003	2,3	22,76	22,72	0,04	0,16	-0,007	-0,009	0,001	16,74	18,40	0,936	0,936	0,000	0,01	18,40	0,00	0,02

	Brick density	U_W type	U_W	U_{av}	ΔU	l_{TB}	Q_{TH}	Q_{FL}	ΔQ	$\Delta Q/Q_{FL}$	Ψ_{TH}	Ψ_{FL}	$\Delta\Psi$	$\Delta\Psi/\Psi_{FL}$	$T_{si,min,TH}$	$f_{Rsi,min,TH}$	$f_{Rsi,min,FL}$	$\Delta f_{Rsi,min}$	$\Delta f_{Rsi,min}/f_{Rsi,min,FL}$	$T_{si,min,FL}$	$\Delta T_{si,min}$	$\Delta T_{si,min}/T_{si,min,FL}$
	(kg/m^3)		(W/m^{2}K)	(W/m^{2}K)	(W/m^{2}K)	(m)	(W)	(W)	(W)	%	(W/mK)	(W/mK)	(W/mK)	%	(°C)	(-)	(-)	(-)	%	(°C)	(°C)	%
PIL.006	1200	U_{max}	0,531	0,707	0,176	2,3	40,66	40,49	0,17	0,41	0,405	0,398	0,007	1,67	13,90	0,756	0,759	0,003	0,44	13,98	0,08	0,59
		U_m	0,293	0,463	0,170	2,3	26,61	26,48	0,13	0,51	0,390	0,385	0,005	1,40	16,20	0,848	0,850	0,002	0,26	16,26	0,05	0,34
		U_{min}	0,210	0,362	0,151	2,3	20,79	20,67	0,12	0,60	0,348	0,343	0,005	1,44	17,20	0,888	0,888	0,000	0,03	17,21	0,01	0,03
		U_x	0,210	0,427	0,217	2,3	24,58	24,48	0,10	0,41	0,499	0,495	0,004	0,80	15,80	0,832	0,832	0,000	0,01	15,80	0,00	0,02
		U_y	0,531	0,515	-0,016	2,3	29,60	29,55	0,04	0,15	-0,038	-0,039	0,002	4,47	17,70	0,908	0,911	0,003	0,30	17,77	0,07	0,38
	1800	U_{max}	0,578	0,792	0,214	2,3	45,54	45,37	0,16	0,36	0,491	0,484	0,007	1,36	13,30	0,732	0,732	0,000	0,02	13,30	0,00	0,02
		U_m	0,316	0,529	0,213	2,3	30,42	30,27	0,14	0,47	0,490	0,484	0,006	1,18	15,70	0,828	0,829	0,001	0,18	15,74	0,04	0,24
		U_{min}	0,223	0,416	0,193	2,3	23,92	23,79	0,14	0,57	0,443	0,438	0,005	1,24	16,80	0,872	0,871	0,001	0,11	16,78	0,02	0,14
		U_x	0,223	0,479	0,255	2,3	27,51	27,42	0,09	0,34	0,587	0,583	0,004	0,65	15,50	0,820	0,820	0,000	0,01	15,50	0,00	0,02
		U_y	0,578	0,558	-0,021	2,3	32,07	32,02	0,05	0,15	-0,048	-0,050	0,002	3,92	17,60	0,904	0,905	0,001	0,09	17,62	0,02	0,12
	760	U_{max}	0,399	0,520	0,121	2,3	29,90	29,75	0,15	0,50	0,278	0,272	0,006	2,16	15,60	0,824	0,828	0,004	0,52	15,71	0,11	0,69
		U_m	0,227	0,330	0,103	2,3	18,96	18,85	0,10	0,55	0,237	0,232	0,004	1,79	17,40	0,896	0,898	0,002	0,21	17,45	0,05	0,27
		U_x	0,170	0,323	0,153	2,3	18,58	18,48	0,10	0,55	0,352	0,348	0,004	1,17	16,70	0,868	0,869	0,001	0,17	16,74	0,04	0,22
		U_y	0,399	0,395	-0,003	2,3	22,74	22,70	0,04	0,17	-0,008	-0,010	0,002	15,79	18,20	0,928	0,930	0,002	0,16	18,24	0,04	0,21

Table 4.1 - Comparison between results obtained through FLUENT and THERM

As it is possible to see in this table, the comparisons have been applied on the heat flow rate Q, the linear thermal transmittance Ψ, the minimum temperature factor at the internal surface $f_{Rsi,min}$ and the minimum internal surface temperature $T_{si,min}$.

The maximum difference between the values obtained through THERM and FLUENT are pointed out with light grey cells and bold style: the high value of ΔQ is equal to 0,18 W, value that determines a ΔΨ equal to 0,007 W/m*K; the high value of $\Delta T_{si,min}$ is equal to 0,13 °C, value that determines a $\Delta f_{Rsi,min}$ equal to 0,005. These values show that these differences are negligible.

But, considering the percentage of these variations on the relative values obtained through FLUENT, the final evaluation is different: for the heat flow, the temperature factor at the internal surface and the internal surface temperature this ratio is near to the 1% and so it's negligible, but the percentage provided by the linear thermal transmittance in more high. The problem is in the cases with U_y (as indicated by grey cells in $\Delta\Psi/\Delta\Psi_{FL}$ column), where the insulation present in the middle of the wall and the one inside or outside of the pillar communicate and so they create a sort of continuous insulation: in this case the heat flow in correspondence of the pillar is very similar of the one in correspondence of the wall and so the linear thermal transmittance is very near to zero. This comports that though ΔΨ is very little, it determines an high error on a Ψ_{FL} so low.

These simulations with U_y had been excluded by the reference correlations, owing to this communication between the two insulations that would have introduced another degree of freedom in this type of junction. However this consideration can become useful in the cases of junctions totally insulated inside or outside, which are very similar to these.

4.3 VALIDATION REPORTS

4.3.1 Reports structure

The validation reports have been structured in two different pages. The first one provides on its summit the reference abacus case being validated with its correlations and confidence intervals. It is important to point out that the reference cases are based on schematization characterized by homogenous layers. In the middle of this form it has been evaluated the influence of real examples, based on non-homogenous stratigraphy. This part in fact reports the values obtained through the simulation on real examples and the values obtained through the reference correlations with the parameters values corresponding to that of the real examples. $\Delta\Psi$ and Δf_{Rsi} represent the differences, and so the error, between these two values respectively for the linear thermal transmittance and the temperature factor at the internal surface. The error is the amount by which the value implied by the estimator differs from the quantity to be estimated.

The chapter **4.2** shows that the difference between the values obtained through FLUENT and THERM has an order of magnitude equal to the third decimal number and so the errors have been evaluated with two decimal numbers.

Using the rules indicated in chapter **4.1**, it has been possible to determine the mean square error (MSE) and its percentage related to the average of the real examples values (MSEP).

For the first cases new correlations have been developed unifying the points of the reference cases with the ones of the validation cases, in order to evaluate how these real examples change the correlations and its confidence interval. The difference between the confidence interval obtained through the validation and the reference one has been evaluated through $\Delta IC_l^{95\%}$ and $\Delta IC_{fRsi}^{95\%}$.

At the end of the first page of the report there is a space dedicated to the development of particular considerations on each case.

The second page report all the stratigraphies with the relative thermal transmittance for each validation case with the results of the minimum surface temperature and the medium thermal transmittance obtained through THERM. The tables provided all the material layers with their thermal conductivity and their thickness. The bold style show the layers that have the greater contribute on the thermal resistance.

The thermal transmittance has been calculated through the following rule:

$$U = \frac{1}{R} = \frac{1}{R_{si} + \frac{L_1}{\lambda_1} + \frac{L_2}{\lambda_2} + \ldots \frac{L_n}{\lambda_n} + R_{se}} \qquad \left(\frac{W}{m^2 \cdot K}\right) \qquad \textit{(4.13)}$$

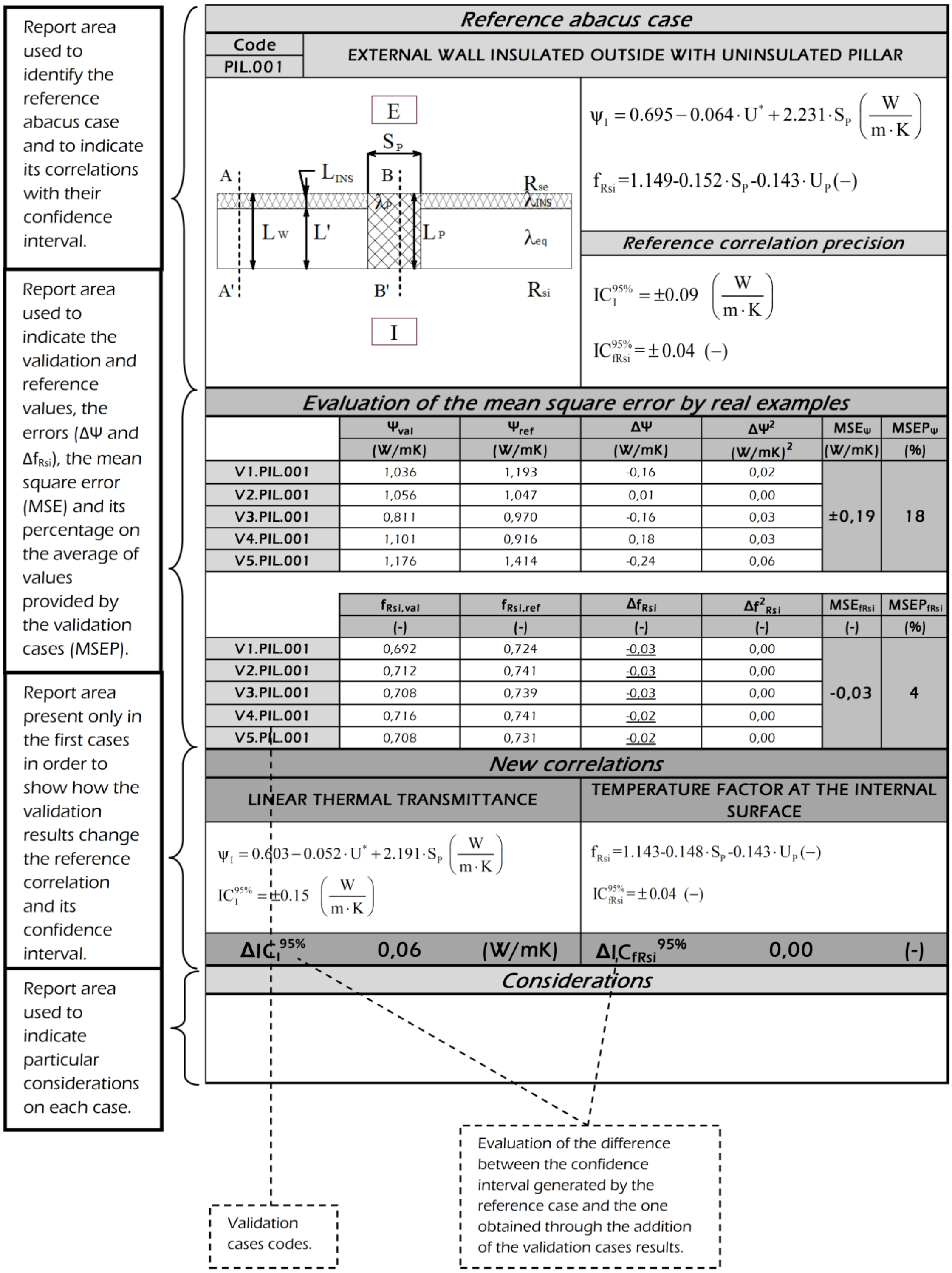
Where:

- L_1, L_2,… L_n are the layers thicknesses;
- L_1, L_2,… L_n are the layers thermal conductivity;
- R_{si} are R_{se} are the surface resistances.

R_{si}	(m^2k/W)	0,13
R_{se}	(m^2k/W)	0,04

Table 4.2 - Surface resistances used in validation

The **Figures 4.2** and **4.3** show the structure of the validation reports.



Report area used to identify the reference abacus case and to indicate its correlations with their confidence interval.

Report area used to indicate the validation and reference values, the errors (ΔΨ and Δf_{Rsi}), the mean square error (MSE) and its percentage on the average of values provided by the validation cases (MSEP).

Report area present only in the first cases in order to show how the validation results change the reference correlation and its confidence interval.

Report area used to indicate particular considerations on each case.

Reference abacus case

Code	
PIL.001	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PILLAR

$$\psi_I = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.149 - 0.152 \cdot S_P - 0.143 \cdot U_P (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val} (W/mK)	Ψ_{ref} (W/mK)	ΔΨ (W/mK)	$\Delta\Psi^2$ $(W/mK)^2$	MSE_Ψ (W/mK)	$MSEP_\Psi$ (%)
V1.PIL.001	1,036	1,193	-0,16	0,02	±0,19	18
V2.PIL.001	1,056	1,047	0,01	0,00		
V3.PIL.001	0,811	0,970	-0,16	0,03		
V4.PIL.001	1,101	0,916	0,18	0,03		
V5.PIL.001	1,176	1,414	-0,24	0,06		

	$f_{Rsi,val}$ (-)	$f_{Rsi,ref}$ (-)	Δf_{Rsi} (-)	Δf^2_{Rsi} (-)	MSE_{fRsi} (-)	$MSEP_{fRsi}$ (%)
V1.PIL.001	0,692	0,724	-0,03	0,00	-0,03	4
V2.PIL.001	0,712	0,741	-0,03	0,00		
V3.PIL.001	0,708	0,739	-0,03	0,00		
V4.PIL.001	0,716	0,741	-0,02	0,00		
V5.PIL.001	0,708	0,731	-0,02	0,00		

New correlations

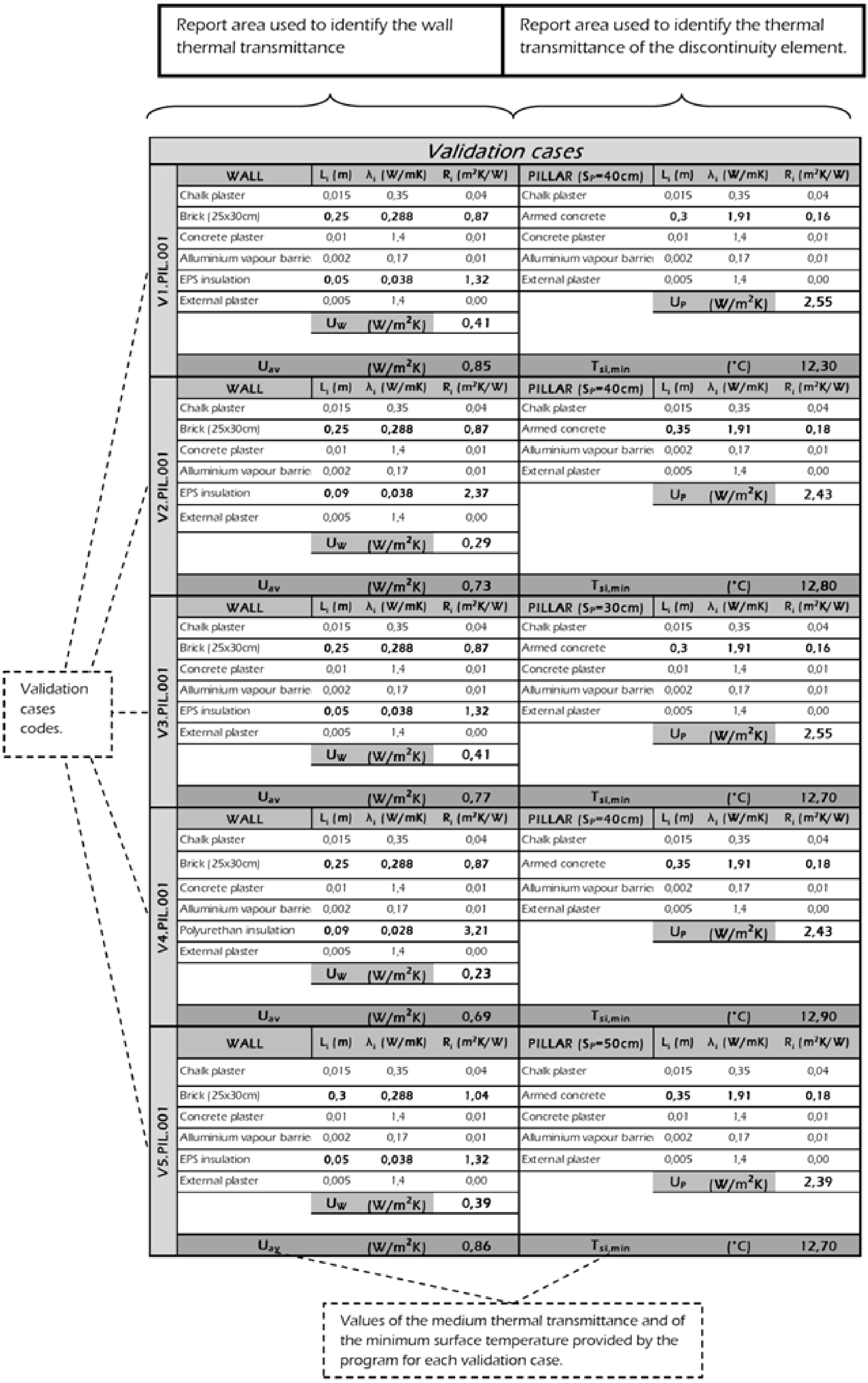
LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.603 - 0.052 \cdot U^* + 2.191 \cdot S_P \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.143 - 0.148 \cdot S_P - 0.143 \cdot U_P (-)$
$IC_I^{95\%} = \pm 0.15 \left(\frac{W}{m \cdot K}\right)$	$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$
$\Delta IC_I^{95\%}$ 0,06 (W/mK)	$\Delta IC_{fRsi}^{95\%}$ 0,00 (-)

Considerations

Validation cases codes.

Evaluation of the difference between the confidence interval generated by the reference case and the one obtained through the addition of the validation cases results.

Figure 4.2 - Structure or the first page of validation reports



Validation cases

Case	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	2,55
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,85	$T_{si,min}$		(°C)	12,30
V2.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^2K)	2,43
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,29				
	U_{av}		(W/m^2K)	0,73	$T_{si,min}$		(°C)	12,80
V3.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	2,55
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,77	$T_{si,min}$		(°C)	12,70
V4.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	Polyurethan insulation	**0,09**	**0,028**	**3,21**		U_P	(W/m^2K)	2,43
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,23				
	U_{av}		(W/m^2K)	0,69	$T_{si,min}$		(°C)	12,90
V5.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	2,39
		U_W	(W/m^2K)	0,39				
	U_{av}		(W/m^2K)	0,86	$T_{si,min}$		(°C)	12,70

Figure 4.3 - Structure of the second page of the validation reports

4.3.2 Junction between external wall and pillar

The fundamental characteristics that change in the stratigraphies of the validation cases are:

- the insulation and brick thickness;
- the insulation and brick thermal conductivity;
- the pillar width.

The reports provided in following pages show that for the first six cases the MSEP is between 18% and 26% for the linear thermal transmittance and it is between 1% and 5% for the temperature factor at the internal surface. This values indicate that the predicted error during a study on real examples isn't so big.

The correlations reported at the end of the reports show the influence of this error on the confidence interval. These correlations have been developed unifying the results used to draw up the reference abacus with the results of the validation cases. For example, taking into consideration the first report (PIL.001), the $\Delta IC_l^{95\%}$ is equal to 0,06 W/m*K because a lot of the validation results are outside the reference confidence interval. Whereas $\Delta IC_{fRsi}^{95\%}$ is equal to 0,00 because the real cases generate a MSEP equal to 4%, but their values are all inside the reference confidence interval.

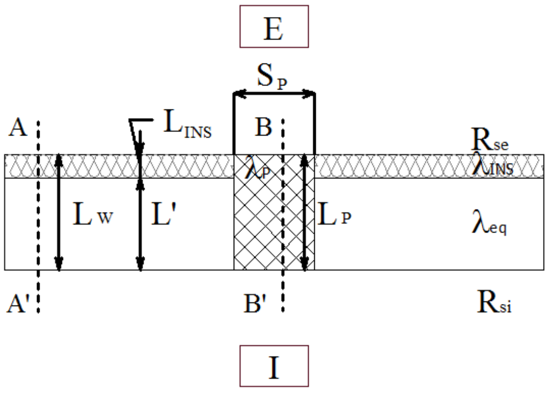
When the validation values are all inside the reference confidence interval, these are underlined.

The last two cases show complete different results: the MSEP for the linear thermal transmittance is so high because it is referred to an initial value equal to zero. This determines that even if the error is low, the MSEP will be very big. In these cases it is necessary to do a more detailed analysis to understand if the error depends on the case itself or on the geometrical model applied. As said before in chapter **4.2**, the different between the results obtained through FLUENT and THERM become more significant in the cases of a continuous insulation. One of the possibilities to solve this problem could be the analysis of the same validation cases through FLUENT and the evaluation of the difference between the values obtained through the two programs.

In these last two cases the MSEP is very low for the temperature factor at the internal surface and so it shows that the reference correlations provide a good representation of the reality.

Reference abacus case

Code	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PILLAR
PIL.001	



$$\psi_I = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.149 - 0.152 \cdot S_P - 0.143 \cdot U_P (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.001	1,036	1,193	-0,16	0,02	±0,19	18
V2.PIL.001	1,056	1,047	0,01	0,00		
V3.PIL.001	0,811	0,970	-0,16	0,03		
V4.PIL.001	1,101	0,916	0,18	0,03		
V5.PIL.001	1,176	1,414	-0,24	0,06		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.001	0,692	0,724	-0,03	0,00	-0,03	4
V2.PIL.001	0,712	0,741	-0,03	0,00		
V3.PIL.001	0,708	0,739	-0,03	0,00		
V4.PIL.001	0,716	0,741	-0,02	0,00		
V5.PIL.001	0,708	0,731	-0,02	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.603 - 0.052 \cdot U^* + 2.191 \cdot S_P \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.15 \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.143 - 0.148 \cdot S_P - 0.143 \cdot U_P (-)$ $IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$
$\Delta IC_I^{95\%}$ 0,06 (W/mK)	$\Delta IC_{fRsi}^{95\%}$ 0,00 (-)

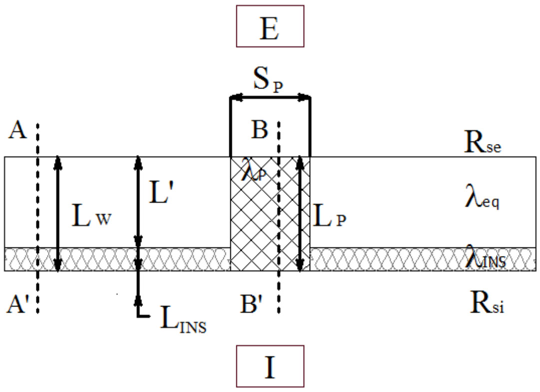
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,55
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,85	$T_{si,min}$		(°C)	12,30
V2.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^{2}K)	2,43
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,73	$T_{si,min}$		(°C)	12,80
V3.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,55
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,77	$T_{si,min}$		(°C)	12,70
V4.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	Polyurethan insulation	**0,09**	**0,028**	**3,21**		U_P	(W/m^{2}K)	2,43
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,23				
	U_{av}		(W/m^{2}K)	0,69	$T_{si,min}$		(°C)	12,90
V5.PIL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,39
		U_W	(W/m^{2}K)	0,39				
	U_{av}		(W/m^{2}K)	0,86	$T_{si,min}$		(°C)	12,70

Reference abacus case

Code	EXTERNAL WALL INSULATED INSIDE WITH UNINSULATED PILLAR
PIL.002	



$$\psi_I = 0.455 - 0.047 \cdot U^* + 2.179 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.933 + 0.051 \cdot S_P - 0.123 \cdot U_P \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.002	0,831	1,054	-0,22	0,05	-0,22	26
V2.PIL.002	0,851	0,954	-0,10	0,01		
V3.PIL.002	0,635	0,836	-0,20	0,04		
V4.PIL.002	0,882	0,864	0,02	0,00		
V5.PIL.002	0,964	1,270	-0,31	0,09		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.002	0,692	0,662	0,03	0,00	+0,03	4
V2.PIL.002	0,700	0,675	0,03	0,00		
V3.PIL.002	0,692	0,657	0,03	0,00		
V4.PIL.002	0,700	0,675	0,03	0,00		
V5.PIL.002	0,708	0,684	0,02	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.344 - 0.034 \cdot U^* + 2.126 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.18 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.950 + 0.045 \cdot S_P - 0.127 \cdot U_P \, (-)$ $IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$
$\Delta IC_I^{95\%}$ 0,10 (W/mK)	**$\Delta IC_{fRsi}^{95\%}$ 0,00 (-)**

Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PIL.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster	0,01	1,4	0,01
	Concrete plaster	0,01	1,4	0,01	Armed concrete	**0,3**	**1,91**	**0,16**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,37
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,75	$T_{si,min}$		(°C)	12,30

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V2.PIL.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	**0,09**	**0,038**	**2,37**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	2,27
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,64	$T_{si,min}$		(°C)	12,50

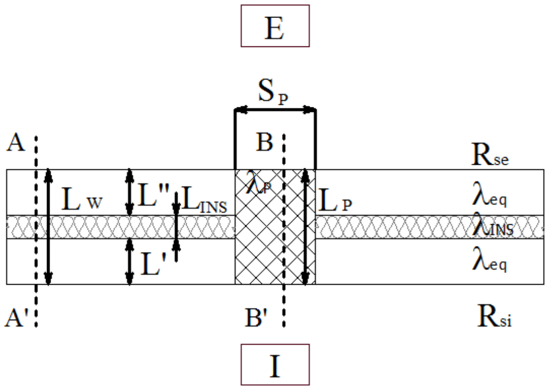
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V3.PIL.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster	0,01	1,4	0,01
	Concrete plaster	0,01	1,4	0,01	Armed concrete	**0,3**	**1,91**	**0,16**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,37
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,68	$T_{si,min}$		(°C)	12,30

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V4.PIL.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	Polyurethan insulation	**0,09**	**0,028**	**3,21**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	2,27
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,23				
	U_{av}		(W/m^{2}K)	0,60	$T_{si,min}$		(°C)	12,50

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V5.PIL.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster	0,01	1,4	0,01
	Concrete plaster	0,01	1,4	0,01	Armed concrete	**0,35**	**1,91**	**0,18**
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,23
		U_W	(W/m^{2}K)	0,38				
	U_{av}		(W/m^{2}K)	0,77	$T_{si,min}$		(°C)	12,70

Reference abacus case

Code	EXTERNAL WALL INSULATED IN THE MIDDLE WITH UNINSULATED PILLAR
PIL.003	



$$\psi_I = 0.650 - 0.060 \cdot U^* + 2.176 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.114 - 0.117 \cdot S_P - 0.143 \cdot U_P (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.02 \ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.003	0,876	1,126	-0,25	0,06	±0,23	25
V2.PIL.003	0,927	0,955	-0,03	0,00		
V3.PIL.003	0,681	0,908	-0,23	0,05		
V4.PIL.003	0,956	0,817	0,14	0,02		
V5.PIL.003	1,070	1,344	-0,27	0,07		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.003	0,720	0,750	-0,03	0,00	-0,03	5
V2.PIL.003	0,720	0,750	-0,03	0,00		
V3.PIL.003	0,724	0,762	-0,04	0,00		
V4.PIL.003	0,720	0,750	-0,03	0,00		
V5.PIL.003	0,712	0,738	-0,03	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.532 - 0.047 \cdot U^* + 2.153 \cdot S_P \quad \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.19 \quad \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.090 - 0.111 \cdot S_P - 0.136 \cdot U_P (-)$ $IC_{fRsi}^{95\%} = \pm 0.03 \ (-)$
$\Delta IC_I^{95\%}$ 0,08 (W/mK)	**$\Delta IC_{fRsi}^{95\%}$ 0,01 (-)**

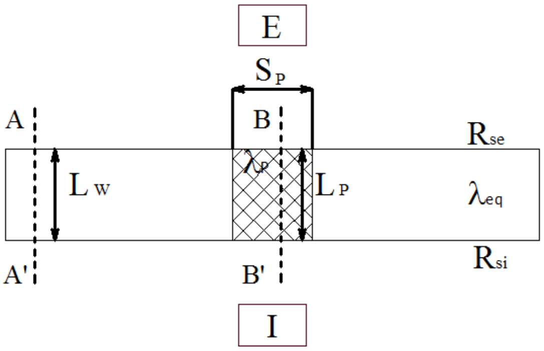
Considerations

Validation cases

V1.PIL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,4**	**1,91**	**0,21**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^{2}K)	2,22
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,70	$T_{si,min}$		(°C)	13,00
V2.PIL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,4**	**1,91**	**0,21**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,11**	**0,038**	**2,89**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^{2}K)	2,22
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,62	$T_{si,min}$		(°C)	13,00
V3.PIL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,4**	**1,91**	**0,21**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^{2}K)	2,22
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,63	$T_{si,min}$		(°C)	13,10
V4.PIL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,4**	**1,91**	**0,21**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Polyurethan insulation	**0,11**	**0,028**	**3,93**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^{2}K)	2,22
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,19				
	U_{av}		(W/m^{2}K)	0,59	$T_{si,min}$		(°C)	13,00
V5.PIL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,4**	**1,91**	**0,21**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^{2}K)	2,22
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,77	$T_{si,min}$		(°C)	12,80

Reference abacus case

Code	UNINSULATED EXTERNAL WALL WITH UNINSULATED PILLAR
PIL.004	



$$\psi_I = 0.436 - 0.769\cdot\lambda_{eq} + 1.656\cdot S_P \quad \left(\frac{W}{m\cdot K}\right)$$

$$f_{Rsi} = 1.070 - 0.070\cdot S_P - 0.138\cdot U_P\,(-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.16 \quad \left(\frac{W}{m\cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.003 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.004	0,781	0,868	-0,09	0,01	**-0,11**	**18**
V2.PIL.004	0,601	0,702	-0,10	0,01		
V3.PIL.004	0,622	0,701	-0,08	0,01		
V4.PIL.004	0,962	1,034	-0,07	0,01		
V5.PIL.004	0,599	0,750	-0,15	0,02		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.004	0,680	0,685	-0,01	0,00	**-0,00**	**1**
V2.PIL.004	0,688	0,692	0,00	0,00		
V3.PIL.004	0,664	0,666	0,00	0,00		
V4.PIL.004	0,676	0,678	0,00	0,00		
V5.PIL.004	0,724	0,728	0,00	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.384 - 0.726\cdot\lambda_{eq} + 1.696\cdot S_P \quad \left(\frac{W}{m\cdot K}\right)$ $IC_I^{95\%} = \pm 0.17 \quad \left(\frac{W}{m\cdot K}\right)$	$f_{Rsi} = 1.066 - 0.068\cdot S_P - 0.137\cdot U_P\,(-)$ $IC_{fRsi}^{95\%} = \pm 0.004 \quad (-)$
$\Delta IC_I^{95\%}$ 0,01 (W/mK)	**$\Delta IC_{fRsi}^{95\%}$ 0,001 (-)**

Considerations

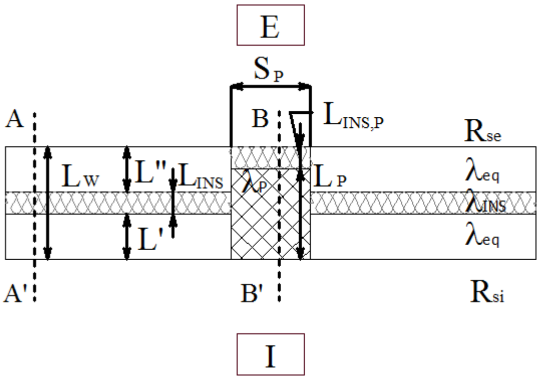
V5.PIL.004 presents a U_P that is outside of the validity field provided by the reference report. The difference between this value and the minimum of the allowed range is low and the generated error is similar to the ones of the other validation cases. As a consequence it is possible to extrapolate the correlation for this value and to considere even this case to evaluate the MSE.

Validation cases

V1.PIL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^2K)	0,79		U_P	(W/m^2K)	2,59
	U_{av}		(W/m^2K)	1,11	$T_{si,min}$		(°C)	12,00
V2.PIL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^2K)	0,79		U_P	(W/m^2K)	2,59
	U_{av}		(W/m^2K)	1,05	$T_{si,min}$		(°C)	12,20
V3.PIL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	0,25	0,288	0,87	Armed concrete	0,25	1,91	0,13
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^2K)	0,91		U_P	(W/m^2K)	2,77
	U_{av}		(W/m^2K)	1,18	$T_{si,min}$		(°C)	11,60
V4.PIL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^2K)	0,79		U_P	(W/m^2K)	2,59
	U_{av}		(W/m^2K)	1,17	$T_{si,min}$		(°C)	11,90
V5.PIL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Concrete bricks	0,4	0,45	0,89	Armed concrete	0,4	1,91	0,21
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^2K)	0,89		U_P	(W/m^2K)	2,28
	U_{av}		(W/m^2K)	1,14	$T_{si,min}$		(°C)	13,10

Reference abacus case

Code	EXTERNAL WALL INSULATED IN THE MIDDLE WITH PILLAR INSULATED OUTSIDE
PIL.005	



$$\psi_I = -0.006 + 0.088 \cdot U^* + 0.528 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.960 - 0.143 \cdot U_P - 0.074 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.03 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.005	0,378	0,306	0,07	0,01	+0,07	20
V2.PIL.005	0,257	0,242	0,02	0,00		
V3.PIL.005	0,335	0,306	0,03	0,00		
V4.PIL.005	0,279	0,261	0,02	0,00		
V5.PIL.005	0,414	0,306	0,11	0,01		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.005	0,840	0,855	-0,02	0,00	-0,02	2
V2.PIL.005	0,872	0,890	-0,02	0,00		
V3.PIL.005	0,828	0,855	-0,03	0,00		
V4.PIL.005	0,884	0,893	-0,01	0,00		
V5.PIL.005	0,852	0,855	0,00	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = 0.015 + 0.0879 \cdot U^* + 0.506 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 0.955 - 0.145 \cdot U_P - 0.068 \cdot \lambda_{eq} (-)$ $IC_{fRsi}^{95\%} = \pm 0.03 \ (-)$
$\Delta IC_I^{95\%}$ 0,00 (W/mK)	**$\Delta IC_{fRsi}^{95\%}$ 0,00 (-)**

Considerations

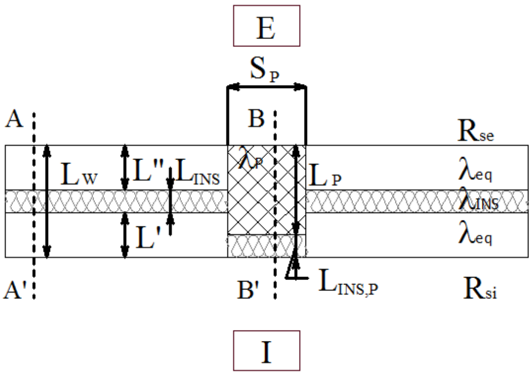
V2.PIL.005 presents a U* that is outside of the validity field provided by the reference report. The difference between this value and the minimum of the allowed range is low and the generated error is similar to the ones of the other validation cases. As a consequence it is possible to extrapolate the correlation for this value and to considere even this case to evaluate the MSE.

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PIL.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,35**	**1,91**	**0,18**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,05**	**0,038**	**1,32**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,49	$T_{si,min}$		(°C)	16,00
V2.PIL.005	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,3**	**1,91**	**0,16**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,1**	**0,038**	**2,63**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	0,33
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,44	$T_{si,min}$		(°C)	16,80
V3.PIL.005	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	**PILLAR (S_P=30cm)**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,35**	**1,91**	**0,18**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,05**	**0,038**	**1,32**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,48	$T_{si,min}$		(°C)	15,70
V4.PIL.005	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,3**	**1,91**	**0,16**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,11**	**0,038**	**2,89**	EPS insulation	**0,1**	**0,038**	**2,63**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	0,33
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,35	$T_{si,min}$		(°C)	17,10
V5.PIL.005	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	**PILLAR (S_P=50cm)**	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,35**	**1,91**	**0,18**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,05**	**0,038**	**1,32**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,50	$T_{si,min}$		(°C)	16,30

Reference abacus case

Code	EXTERNAL WALL INSULATED IN THE MIDDLE WITH PILLAR INSULATED INSIDE
PIL.006	



$$\psi_I = -0.001 + 0.093 \cdot U^* + 0.510 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.014 - 0.247 \cdot U_P - 0.126 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.04 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.006	0,285	0,314	-0,03	0,00	-0,06	23
V2.PIL.006	0,156	0,234	-0,08	0,01		
V3.PIL.006	0,261	0,314	-0,05	0,00		
V4.PIL.006	0,181	0,249	-0,07	0,00		
V5.PIL.006	0,313	0,314	0,00	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.006	0,860	0,833	0,03	0,00	+0,03	3
V2.PIL.006	0,912	0,901	0,01	0,00		
V3.PIL.006	0,864	0,833	0,03	0,00		
V4.PIL.006	0,912	0,900	0,01	0,00		
V5.PIL.006	0,860	0,833	0,03	0,00		

New correlations

LINEAR THERMAL TRANSMITTANCE	TEMPERATURE FACTOR AT THE INTERNAL SURFACE
$\psi_I = -0.027 + 0.097 \cdot U^* + 0.535 \cdot \lambda_{eq} \left(\frac{W}{m \cdot K}\right)$ $IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$	$f_{Rsi} = 1.019 - 0.242 \cdot U_P - 0.136 \cdot \lambda_{eq} (-)$ $IC_{fRsi}^{95\%} = \pm 0.04 \; (-)$
$\Delta IC_I^{95\%}$ 0,00 (W/mK)	**$\Delta IC_{fRsi}^{95\%}$ 0,00 (-)**

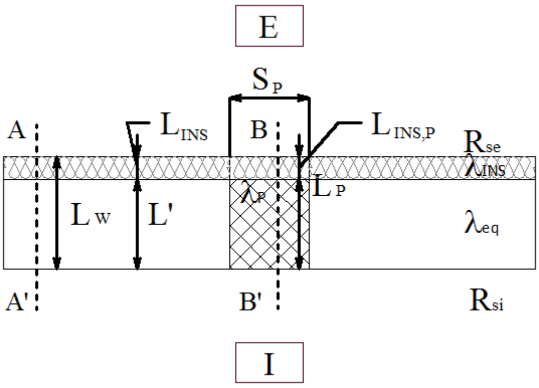
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PIL.006	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	0,08	0,3	0,27	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	0,05	0,038	1,32
	EPS insulation	0,06	0,038	1,58	Armed concrete	0,35	1,91	0,18
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,46	$T_{si,min}$		(°C)	16,50
V2.PIL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=12cm)	0,12	0,232	0,52	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	0,1	0,038	2,63
	EPS insulation	0,07	0,038	1,84	Armed concrete	0,3	1,91	0,16
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (L=20cm)	0,2	0,239	0,84		U_P	(W/m^{2}K)	0,33
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,36	$T_{si,min}$		(°C)	17,80
V3.PIL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	0,08	0,3	0,27	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	0,05	0,038	1,32
	EPS insulation	0,06	0,038	1,58	Armed concrete	0,35	1,91	0,18
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,45	$T_{si,min}$		(°C)	16,60
V4.PIL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (W/m^{2}K)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=12cm)	0,12	0,232	0,52	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	0,1	0,038	2,63
	EPS insulation	0,1	0,038	2,63	Armed concrete	0,25	1,91	0,13
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (L=12cm)	0,12	0,232	0,52		U_P	(W/m^{2}K)	0,33
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,26				
	U_{av}		(W/m^{2}K)	0,33	$T_{si,min}$		(°C)	17,80
V5.PIL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (L=8cm)	0,08	0,3	0,27	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	0,05	0,038	1,32
	EPS insulation	0,06	0,038	1,58	Armed concrete	0,35	1,91	0,18
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^{2}K)	0,57
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,46	$T_{si,min}$		(°C)	16,50

Reference abacus case

Code	EXTERNAL WALL INSULATED OUTSIDE WITH PILLAR INSULATED OUTSIDE
PIL.007	



$$\psi_I = 0 \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1\text{-}R_{si} \cdot U_P (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.007	0,113	0,000	0,11	0,01	+0,10	110
V2.PIL.007	0,029	0,000	0,03	0,00		
V3.PIL.007	0,091	0,000	0,09	0,01		
V4.PIL.007	0,134	0,000	0,13	0,02		
V5.PIL.007	0,024	0,000	0,02	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.007	0,904	0,924	-0,02	0,00	-0,02	2
V2.PIL.007	0,944	0,957	-0,01	0,00		
V3.PIL.007	0,900	0,924	-0,02	0,00		
V4.PIL.007	0,908	0,924	-0,02	0,00		
V5.PIL.007	0,956	0,967	-0,01	0,00		

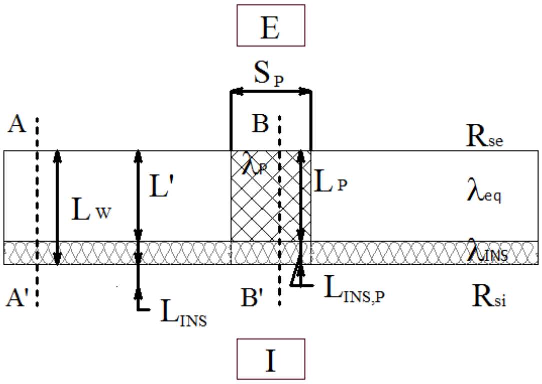
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PIL.007	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	EPS insulation	**0,05**	**0,038**	**1,32**
	External plaster	0,005	1,4	0,00	External plaster	0,005	1,4	0,00
		U_W	(W/m^2K)	0,39		U_P	(W/m^2K)	0,59
	U_{av}		(W/m^2K)	0,43	$T_{si,min}$		(°C)	17,60
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V2.PIL.007	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,1**	**0,038**	**2,63**	EPS insulation	**0,1**	**0,038**	**2,63**
	External plaster	0,005	1,4	0,00	External plaster	0,005	1,4	0,00
		U_W	(W/m^2K)	0,26		U_P	(W/m^2K)	0,33
	U_{av}		(W/m^2K)	0,27	$T_{si,min}$		(°C)	18,60
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V3.PIL.007	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	EPS insulation	**0,05**	**0,038**	**1,32**
	External plaster	0,005	1,4	0,00	External plaster	0,005	1,4	0,00
		U_W	(W/m^2K)	0,39		U_P	(W/m^2K)	0,59
	U_{av}		(W/m^2K)	0,43	$T_{si,min}$		(°C)	17,50
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V4.PIL.007	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	EPS insulation	**0,05**	**0,038**	**1,32**
	External plaster	0,005	1,4	0,00	External plaster	0,005	1,4	0,00
		U_W	(W/m^2K)	0,39		U_P	(W/m^2K)	0,59
	U_{av}		(W/m^2K)	0,44	$T_{si,min}$		(°C)	17,70
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V5.PIL.007	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,25**	**1,91**	**0,13**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,4	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Polyurethan insulation	**0,1**	**0,028**	**3,57**	Polyurethan insulation	**0,1**	**0,028**	**3,57**
	External plaster	0,005	1,4	0,00	External plaster	0,005	1,4	0,00
		U_W	(W/m^2K)	0,21		U_P	(W/m^2K)	0,25
	U_{av}		(W/m^2K)	0,22	$T_{si,min}$		(°C)	18,90

Reference abacus case

Code	EXTERNAL WALL INSULATED INSIDE WITH PILLAR INSULATED INSIDE
PIL.008	



$$\psi_I = 0 \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1 - R_{si} \cdot U_P \, (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.008	0,110	0,000	0,11	0,01	+0,10	111
V2.PIL.008	0,044	0,000	0,04	0,00		
V3.PIL.008	0,089	0,000	0,09	0,01		
V4.PIL.008	0,130	0,000	0,13	0,02		
V5.PIL.008	0,023	0,000	0,02	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.008	0,928	0,925	0,00	0,00	+0,00	0
V2.PIL.008	0,960	0,957	0,00	0,00		
V3.PIL.008	0,932	0,925	0,01	0,00		
V4.PIL.008	0,928	0,925	0,00	0,00		
V5.PIL.008	0,968	0,967	0,00	0,00		

Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PIL.008	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,04	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,40	0,01
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^{2}K)	0,38		U_P	(W/m^{2}K)	0,58
	U_{av}		(W/m^{2}K)	0,43	$T_{si,min}$		(°C)	18,20
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V2.PIL.008	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	0,1	0,038	2,63	EPS insulation	0,1	0,04	2,63
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,40	0,01
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^{2}K)	0,25		U_P	(W/m^{2}K)	0,33
	U_{av}		(W/m^{2}K)	0,27	$T_{si,min}$		(°C)	19,00
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V3.PIL.008	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,04	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,40	0,01
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^{2}K)	0,38		U_P	(W/m^{2}K)	0,58
	U_{av}		(W/m^{2}K)	0,42	$T_{si,min}$		(°C)	18,30
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V4.PIL.008	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,04	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,40	0,01
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,3	1,91	0,16
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^{2}K)	0,38		U_P	(W/m^{2}K)	0,58
	U_{av}		(W/m^{2}K)	0,43	$T_{si,min}$		(°C)	18,20
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V5.PIL.008	Plasterboard	0,015	0,21	0,07	Plasterboard	0,015	0,21	0,07
	Polyurethan insulation	0,1	0,028	3,57	Polyurethan insulation	0,1	0,03	3,57
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,01	1,40	0,01
	Brick (25x30cm)	0,25	0,288	0,87	Armed concrete	0,25	1,91	0,13
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,015	0,9	0,02
		U_W	(W/m^{2}K)	0,21		U_P	(W/m^{2}K)	0,25
	U_{av}		(W/m^{2}K)	0,22	$T_{si,min}$		(°C)	19,20

4.3.3 Projecting corners

The fundamental characteristics that change in the stratigraphies of the validation cases are:

- the insulation and brick thickness;
- the insulation and brick thermal conductivity;
- the pillar dimensions.

A particular case simulated in this study is the V5.PC.004, in which the pillar has a rectangular shape. This characteristic has never been considered to draw up the reference abacus. For this case the pillar thermal transmittance has been calculated on a length equal to that of the quadratic pillar, as it is shown in this figure.

For the most part of these building junctions the MSEP for linear thermal transmittance is between 5% and 29%. This means that the expected error in real cases isn't so high.

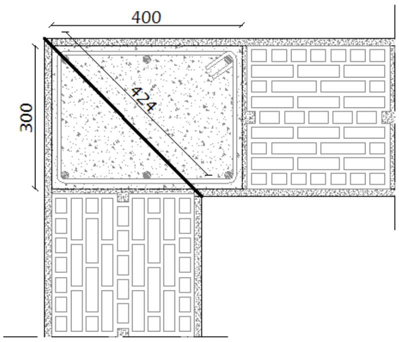


Figure 4.4 - Rectangular pillar case

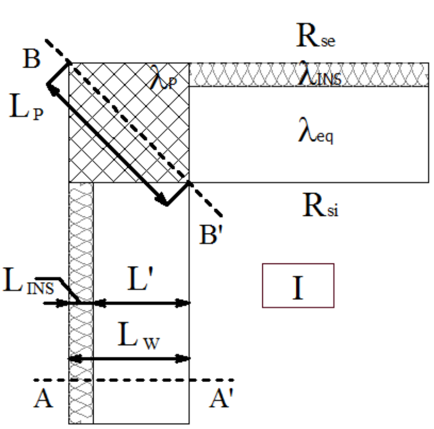
The exceptions are PC.005 that, owing to the continuity of the insulation present a greater MSEP (46%) and PC.009 in which the reference correlations provide negative values of the linear thermal transmittance, whereas the real building junctions, based on a non-homogenous stratigraphy, determine positive values of it. The difference between these results increase a lot the MSEP.

Probably the non-homogeneity of the layers determine the change of the heat flow direction.

The MSEP for the temperature factor at the internal surface is always between 1% and 11% and so the expected error is very small. This indicates that the non-homogeneity of the layers composing the wall has a smaller influence on the temperature factor at the internal surface than on the linear thermal transmittance.

Reference abacus case

Code	PROJECTING CORNER INSULATED OUTSIDE WITH UNINSULATED PILLAR
PC.001	



$$\psi_I = -0.018 + 0.036 \cdot U^* + 0.996 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.632 - 0.246 \cdot U_W + 0.128 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.001	0,458	0,463	0,00	0,00	-0,03	6
V2.PC.001	0,509	0,527	-0,02	0,00		
V3.PC.001	0,414	0,421	-0,01	0,00		
V4.PC.001	0,538	0,587	-0,05	0,00		
V5.PC.001	0,441	0,453	-0,01	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.001	0,628	0,569	0,06	0,00	+0,06	9
V2.PC.001	0,640	0,600	0,04	0,00		
V3.PC.001	0,640	0,577	0,06	0,00		
V4.PC.001	0,644	0,614	0,03	0,00		
V5.PC.001	0,644	0,589	0,05	0,00		

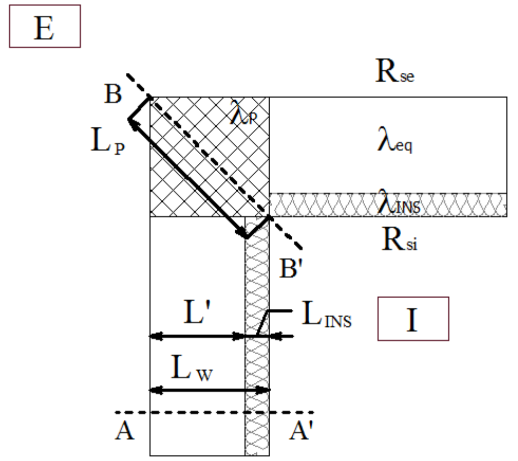
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PC.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,06
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,65	$T_{si,min}$		(°C)	10,70
V2.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,007	1,4	0,01
	EPS insulation	**0,09**	**0,038**	2,37		U_P	(W/m^{2}K)	1,96
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,55	$T_{si,min}$		(°C)	11,00
V3.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,3**	**0,23**	**1,30**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	1,92
		U_W	(W/m^{2}K)	0,35				
	U_{av}		(W/m^{2}K)	0,56	$T_{si,min}$		(°C)	11,00
V4.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,007	1,4	0,01
	Polyurethan insulation	**0,09**	**0,028**	**3,21**		U_P	(W/m^{2}K)	1,96
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,23				
	U_{av}		(W/m^{2}K)	0,50	$T_{si,min}$		(°C)	11,10
V5.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,3**	**0,23**	**1,30**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	1,92
		U_W	(W/m^{2}K)	0,30				
	U_{av}		(W/m^{2}K)	0,52	$T_{si,min}$		(°C)	11,10

Reference abacus case

Code	PROJECTING CORNER INSULATED INSIDE WITH UNINSULATED PILLAR
PC.002	



$$\psi_I = 0.071 + 0.007 \cdot U^* - 0.017 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.738 - 0.034 \cdot U_W (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.002 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.002	0,116	0,099	0,02	0,00	±0,02	16
V2.PC.002	0,119	0,110	0,01	0,00		
V3.PC.002	0,132	0,103	0,03	0,00		
V4.PC.002	0,106	0,121	-0,01	0,00		
V5.PC.002	0,115	0,109	0,01	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.002	0,716	0,724	-0,01	0,00	-0,01	1
V2.PC.002	0,716	0,728	-0,01	0,00		
V3.PC.002	0,716	0,726	-0,01	0,00		
V4.PC.002	0,728	0,730	0,00	0,00		
V5.PC.002	0,728	0,728	0,00	0,00		

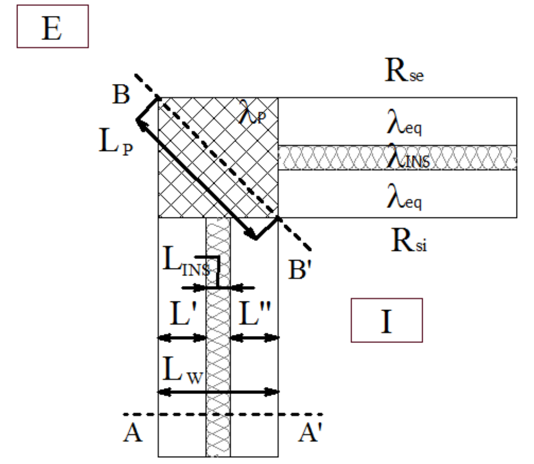
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PC.002	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,05**	**0,038**	**1,32**	Armed concrete	**0,424**	**1,91**	**0,22**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Concrete plaster with san	0,021	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	**1,94**
		U_W	(W/m^{2}K)	**0,41**				
	U_{av}		(W/m^{2}K)	**0,47**	$T_{si,min}$		(°C)	**12,90**
V2.PC.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,09**	**0,038**	**2,37**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	**1,81**
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	**0,29**				
	U_{av}		(W/m^{2}K)	**0,35**	$T_{si,min}$		(°C)	**12,90**
V3.PC.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,05**	**0,038**	**1,32**	Armed concrete	**0,495**	**1,91**	**0,26**
	Lightened bricks	**0,3**	**0,23**	**1,30**	Concrete plaster with san	0,021	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	**1,81**
		U_W	(W/m^{2}K)	**0,35**				
	U_{av}		(W/m^{2}K)	**0,41**	$T_{si,min}$		(°C)	**12,90**
V4.PC.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	Polyurethan insulation	**0,09**	**0,028**	**3,21**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	**1,81**
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	**0,23**				
	U_{av}		(W/m^{2}K)	**0,28**	$T_{si,min}$		(°C)	**13,20**
V5.PC.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	Armed concrete	**0,495**	**1,91**	**0,26**
	Lightened bricks	**0,3**	**0,23**	**1,30**	Concrete plaster with san	0,021	0,9	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	**1,81**
		U_W	(W/m^{2}K)	**0,30**				
	U_{av}		(W/m^{2}K)	**0,36**	$T_{si,min}$		(°C)	**13,20**

Reference abacus case

Code	PROJECTING CORNER INSULATED IN THE MIDDLE WITH UNINSULATED PILLAR
PC.003	



$$\psi_I = 0.080 + 0.026 \cdot U^* + 0.664 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.628 - 0.252 \cdot U_W + 0.117 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.003	0,344	0,419	-0,08	0,01	-0,10	29
V2.PC.003	0,359	0,456	-0,10	0,01		
V3.PC.003	0,348	0,401	-0,05	0,00		
V4.PC.003	0,364	0,503	-0,14	0,02		
V5.PC.003	0,349	0,406	-0,06	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.003	0,636	0,579	0,06	0,00	+0,05	9
V2.PC.003	0,636	0,601	0,04	0,00		
V3.PC.003	0,632	0,574	0,06	0,00		
V4.PC.003	0,640	0,612	0,03	0,00		
V5.PC.003	0,640	0,584	0,06	0,00		

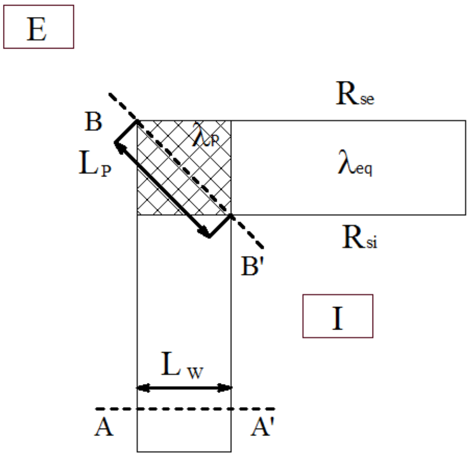
Considerations

Validation cases

V1.PC.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (40x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,566**	**1,91**	**0,30**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	1,76
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,34				
	U_{av}		(W/m^2K)	0,51	$T_{si,min}$		(°C)	10,90
V2.PC.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (40x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,566**	**1,91**	**0,30**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,11**	**0,038**	**2,89**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	1,76
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,24				
	U_{av}		(W/m^2K)	0,42	$T_{si,min}$		(°C)	10,90
V3.PC.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,495**	**1,91**	**0,26**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	1,89
	Lightened bricks	**0,2**	**0,23**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,34				
	U_{av}		(W/m^2K)	0,51	$T_{si,min}$		(°C)	10,80
V4.PC.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (40x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,566**	**1,91**	**0,30**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	Polyurethan insulation	**0,11**	**0,028**	**3,93**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	1,76
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,19				
	U_{av}		(W/m^2K)	0,37	$T_{si,min}$		(°C)	11,00
V5.PC.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (40x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=12cm)	**0,12**	**0,232**	**0,52**	Armed concrete	**0,566**	**1,91**	**0,30**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	EPS insulation	**0,07**	**0,038**	**1,84**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	1,76
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,29				
	U_{av}		(W/m^2K)	0,47	$T_{si,min}$		(°C)	11,00

Reference abacus case

Code	UNINSULATED PROJECTING CORNER WITH UNINSULATED PILLAR
PC.004	



$$\psi_I = 0.350 - 0.003 \cdot U^* + 0.103 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.592 - 0.125 \cdot U_W + 0.194 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \;\; (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.004	0,305	0,373	-0,07	0,00	±0,08	26
V2.PC.004	0,279	0,374	-0,09	0,01		
V3.PC.004	0,291	0,365	-0,07	0,01		
V4.PC.004	0,375	0,391	-0,02	0,00		
V5.PC.004	0,471	0,373	0,10	0,01		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.004	0,608	0,552	0,06	0,00	±0,06	11
V2.PC.004	0,592	0,537	0,06	0,00		
V3.PC.004	0,620	0,557	0,06	0,00		
V4.PC.004	0,616	0,568	0,05	0,00		
V5.PC.004	0,544	0,552	-0,01	0,00		

Considerations

In this case it is possible to see that V5.PC.004 is the case which change the errorsign for the linear thermal transmittance. This is due to the different pillar geometry: in the reference cases it is always quadratic, instead in this case it is rectangular.

Validation cases

V1.PC.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,424	1,91	0,22
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,79		U_P	(W/m^2K)	2,10
	U_{av}		(W/m^2K)	0,94	$T_{si,min}$		(°C)	10,20

V2.PC.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	0,25	0,288	0,87	Armed concrete	0,354	1,91	0,19
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,91		U_P	(W/m^2K)	2,28
	U_{av}		(W/m^2K)	1,05	$T_{si,min}$		(°C)	9,80

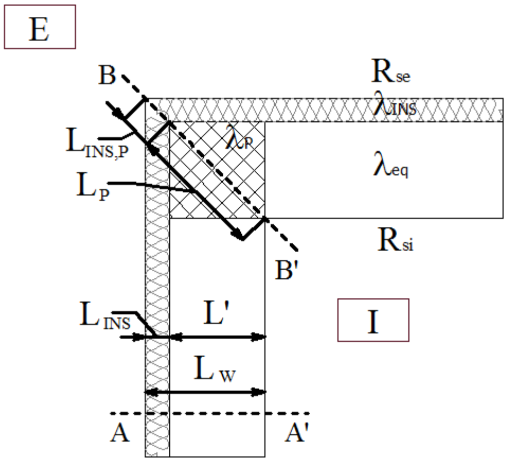
V3.PC.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	0,3	0,23	1,30	Armed concrete	0,424	1,91	0,22
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,65		U_P	(W/m^2K)	2,10
	U_{av}		(W/m^2K)	0,80	$T_{si,min}$		(°C)	10,50

V4.PC.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (40x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Concrete bricks	0,4	0,45	0,89	Armed concrete	0,566	1,91	0,30
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,89		U_P	(W/m^2K)	1,82
	U_{av}		(W/m^2K)	1,08	$T_{si,min}$		(°C)	10,40

V5.PC.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (30x40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (30x30cm)	0,3	0,288	1,04	Armed concrete	0,424	1,91	0,22
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,79		U_P	(W/m^2K)	2,10
	U_{av}		(W/m^2K)	1,03	$T_{si,min}$		(°C)	8,60

Reference abacus case

Code	PROJECTING CORNER INSULATED OUTSIDE WITH PILLAR INSULATED OUTSIDE
PC.005	



$$\psi_I = 0.385 - 0.116 \cdot U^* - 0.198 \cdot L_W \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.880 - 0.319 \cdot U_P + 0.106 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.005	0,185	0,198	-0,01	0,00	-0,07	46
V2.PC.005	0,136	0,205	-0,07	0,00		
V3.PC.005	0,171	0,181	-0,01	0,00		
V4.PC.005	0,113	0,211	-0,10	0,01		
V5.PC.005	0,139	0,237	-0,10	0,01		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.005	0,788	0,774	0,01	0,00	±0,02	3
V2.PC.005	0,856	0,836	0,02	0,00		
V3.PC.005	0,808	0,800	0,01	0,00		
V4.PC.005	0,884	0,854	0,03	0,00		
V5.PC.005	0,824	0,835	-0,01	0,00		

Considerations

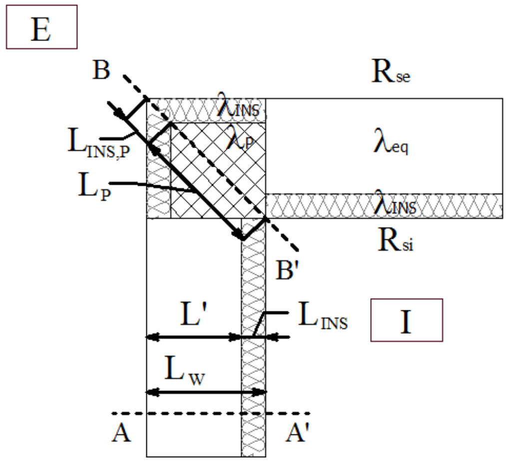
V5.PC.005 presents a U* that is outside of the validity field provided by the reference report. The difference between this value and the minimum of the allowed range is low, but the generated error is very significant. As a consequence, this value has been excluded by the evaluation of the MSE for the linear thermal transmittance.

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PC.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,05**	**0,038**	**1,32**	EPS insulation	**0,071**	**0,038**	**1,86**
	External plaster	0,005	1,4	0,00	External plaster	0,007	1,4	0,01
		U_W	(W/m^2K)	0,41		U_P	(W/m^2K)	0,43
	U_{av}		(W/m^2K)	0,51	$T_{si,min}$		(°C)	14,70
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V2.PC.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,1**	**0,038**	**2,63**	EPS insulation	**0,141**	**0,038**	**3,72**
	External plaster	0,005	1,4	0,00	External plaster	0,007	1,4	0,01
		U_W	(W/m^2K)	0,27		U_P	(W/m^2K)	0,24
	U_{av}		(W/m^2K)	0,34	$T_{si,min}$		(°C)	16,40
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V3.PC.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,3**	**0,23**	**1,30**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	Polyurethan insulation	**0,071**	**0,028**	**2,53**
	External plaster	0,005	1,4	0,00	External plaster	0,007	1,4	0,01
		U_W	(W/m^2K)	0,30		U_P	(W/m^2K)	0,33
	U_{av}		(W/m^2K)	0,39	$T_{si,min}$		(°C)	15,20
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V4.PC.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	Polyurethan insulation	**0,1**	**0,028**	**3,57**	Polyurethan insulation	**0,141**	**0,028**	**5,05**
	External plaster	0,005	1,4	0,00	External plaster	0,007	1,4	0,01
		U_W	(W/m^2K)	0,21		U_P	(W/m^2K)	0,18
	U_{av}		(W/m^2K)	0,27	$T_{si,min}$		(°C)	17,10
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V5.PC.005	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster	0,014	1,400	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,05**	**0,038**	**1,32**	EPS insulation	**0,141**	**0,038**	**3,72**
	External plaster	0,005	1,4	0,00	External plaster	0,007	1,4	0,01
		U_W	(W/m^2K)	0,39		U_P	(W/m^2K)	0,24
	U_{av}		(W/m^2K)	0,46	$T_{si,min}$		(°C)	15,60

Reference abacus case

Code	PROJECTING CORNER INSULATED INSIDE WITH PILLAR INSULATED OUTSIDE
PC.006	



$$\psi_I = 0.072 + 0.012\cdot U^* - 0.023\cdot \lambda_{eq} \quad \left(\frac{W}{m\cdot K}\right)$$

$$f_{Rsi} = 0.809 - 0.069\cdot U_P - 0.057\cdot \lambda_{eq}\,(-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.06 \quad \left(\frac{W}{m\cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.006	0,083	0,078	0,01	0,00	+0,00	5
V2.PC.006	0,081	0,075	0,01	0,00		
V3.PC.006	0,082	0,080	0,00	0,00		
V4.PC.006	0,075	0,075	0,00	0,00		
V5.PC.006	0,075	0,073	0,00	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.006	0,752	0,763	-0,01	0,00	-0,01	1
V2.PC.006	0,764	0,775	-0,01	0,00		
V3.PC.006	0,768	0,773	0,00	0,00		
V4.PC.006	0,772	0,779	-0,01	0,00		
V5.PC.006	0,768	0,776	-0,01	0,00		

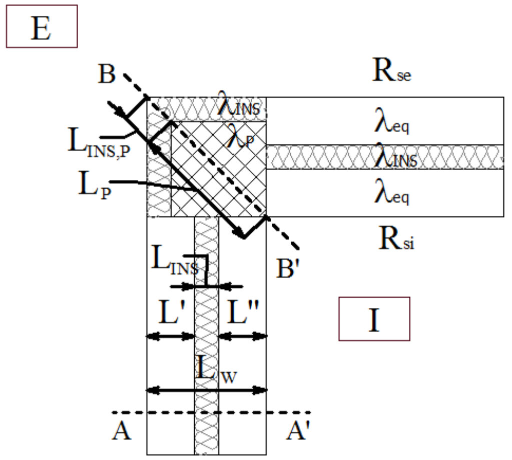
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PC.006	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,05**	**0,038**	**1,32**	Armed concrete	**0,354**	**1,91**	**0,19**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	EPS insulation	**0,071**	**0,038**	**1,86**
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,41		U_P	(W/m^2K)	0,43
	U_{av}		(W/m^2K)	0,45	$T_{si,min}$		(°C)	13,80
V2.PC.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,09**	**0,038**	**2,37**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	EPS insulation	**0,141**	**0,038**	**3,72**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^2K)	0,24
		U_W	(W/m^2K)	0,29				
	U_{av}		(W/m^2K)	0,33	$T_{si,min}$		(°C)	14,10
V3.PC.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	Armed concrete	**0,424**	**1,91**	**0,22**
	Lightened bricks	**0,3**	**0,23**	**1,30**	Polyurethan insulation	**0,071**	**0,028**	**2,53**
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,30		U_P	(W/m^2K)	0,33
	U_{av}		(W/m^2K)	0,34	$T_{si,min}$		(°C)	14,20
V4.PC.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	Polyurethan insulation	**0,09**	**0,028**	**3,21**	Armed concrete	**0,354**	**1,91**	**0,19**
	Concrete plaster	0,01	1,4	0,01	Polyurethan insulation	**0,141**	**0,028**	**5,05**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Concrete plaster with san	0,021	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^2K)	0,18
		U_W	(W/m^2K)	0,23				
	U_{av}		(W/m^2K)	0,27	$T_{si,min}$		(°C)	14,30
V5.PC.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Plasterboard	0,021	0,21	0,10
	EPS insulation	**0,05**	**0,038**	**1,32**	Armed concrete	**0,354**	**1,91**	**0,19**
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	EPS insulation	**0,141**	**0,038**	**3,72**
	Concrete plaster with san	0,015	0,9	0,02	Concrete plaster with san	0,021	0,900	0,02
		U_W	(W/m^2K)	0,38		U_P	(W/m^2K)	0,24
	U_{av}		(W/m^2K)	0,42	$T_{si,min}$		(°C)	14,20

Reference abacus case

Code	PROJECTING CORNER INSULATED IN THE MIDDLE WITH PILLAR INSULATED OUTSIDE
PC.007	



$$\psi_I = 0.084 + 0.053\cdot U^* + 0.481\cdot\lambda_{eq}\ \left(\frac{W}{m\cdot K}\right)$$

$$f_{Rsi} = 0.815 - 0.276\cdot U_p + 0.019\cdot\lambda_{eq}\,(-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.11\ \left(\frac{W}{m\cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.02\ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.007	0,244	0,297	-0,05	0,00	-0,06	25
V2.PC.007	0,213	0,268	-0,06	0,00		
V3.PC.007	0,244	0,277	-0,03	0,00		
V4.PC.007	0,214	0,266	-0,05	0,00		
V5.PC.007	0,186	0,252	-0,07	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.007	0,708	0,705	0,00	0,00	±0,00	1
V2.PC.007	0,756	0,755	0,00	0,00		
V3.PC.007	0,732	0,729	0,00	0,00		
V4.PC.007	0,764	0,770	-0,01	0,00		
V5.PC.007	0,756	0,754	0,00	0,00		

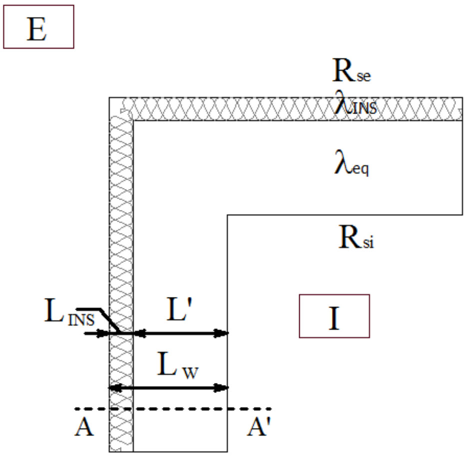
Considerations

V5.PC.007 presents a U* that is outside of the validity field provided by the reference report. The difference between this value and the minimum of the allowed range is low, but the generated error is very significant. As a consequence, this value has been excluded by the evaluation of the MSE for the linear thermal transmittance.

Validation cases								
V1.PC.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,495**	**1,91**	**0,26**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,071**	**0,038**	**1,86**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	0,42
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,46	$T_{si,min}$		(°C)	12,70
V2.PC.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,424**	**1,91**	**0,22**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	EPS insulation	**0,11**	**0,038**	**2,89**	EPS insulation	**0,141**	**0,038**	**3,72**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	0,24
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,34	$T_{si,min}$		(°C)	13,90
V3.PC.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=12cm)	**0,12**	**0,232**	**0,52**	Armed concrete	**0,495**	**1,91**	**0,26**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Polyurethan insulation	**0,07**	**0,028**	**2,50**	Polyurethan insulation	**0,071**	**0,028**	**2,53**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	0,33
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,37	$T_{si,min}$		(°C)	13,30
V4.PC.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,424**	**1,91**	**0,22**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,170	0,02
	Polyurethan insulation	**0,11**	**0,028**	**3,93**	Polyurethan insulation	**0,141**	**0,028**	**5,05**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	0,18
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,19				
	U_{av}		(W/m^{2}K)	0,30	$T_{si,min}$		(°C)	14,10
V5.PC.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (25x25cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Armed concrete	**0,354**	**1,91**	**0,19**
	Alluminium vapour barrie	0,002	0,17	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**	EPS insulation	**0,141**	**0,038**	**3,72**
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,021	0,900	0,02
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	0,24
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,44	$T_{si,min}$		(°C)	13,90

Reference abacus case

Code	
PC.008	PROJECTING CORNER INSULATED OUTSIDE WITHOUT PILLAR



$$\psi_I = 0.047 + 0.092 \cdot U_W + 0.127 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.968 - 0.235 \cdot U_W + 0.012 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.03 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.008	0,125	0,123	0,00	0,00	±0,01	7
V2.PC.008	0,104	0,110	-0,01	0,00		
V3.PC.008	0,111	0,110	0,00	0,00		
V4.PC.008	0,091	0,105	-0,01	0,00		
V5.PC.008	0,106	0,105	0,00	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.008	0,860	0,874	-0,01	0,00	-0,01	1
V2.PC.008	0,900	0,909	-0,01	0,00		
V3.PC.008	0,876	0,889	-0,01	0,00		
V4.PC.008	0,920	0,921	0,00	0,00		
V5.PC.008	0,888	0,900	-0,01	0,00		

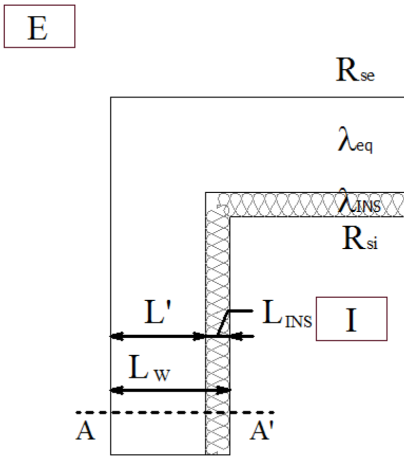
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PC.008	Chalk plaster	0,015	0,35	0,04				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster	0,01	1,4	0,01				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,05**	**0,038**	**1,32**				
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,48	$T_{si,min}$		(°C)	16,50
V2.PC.008	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster	0,01	1,4	0,01				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,1**	**0,038**	**2,63**				
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	
		U_W	(W/m^2K)	0,27				
	U_{av}		(W/m^2K)	0,32	$T_{si,min}$		(°C)	17,50
V3.PC.008	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04				
	Lightened bricks	**0,3**	**0,23**	**1,30**				
	Concrete plaster	0,01	1,4	0,01				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,05**	**0,038**	**1,32**				
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	
		U_W	(W/m^2K)	0,35				
	U_{av}		(W/m^2K)	0,41	$T_{si,min}$		(°C)	16,90
V4.PC.008	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster	0,01	1,4	0,01				
	Alluminium vapour barrie	0,002	0,17	0,01				
	Polyurethan insulation	**0,1**	**0,028**	**3,57**				
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	
		U_W	(W/m^2K)	0,21				
	U_{av}		(W/m^2K)	0,26	$T_{si,min}$		(°C)	18,00
V5.PC.008	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04				
	Lightened bricks	**0,3**	**0,23**	**1,30**				
	Concrete plaster	0,01	1,4	0,01				
	Alluminium vapour barrie	0,002	0,17	0,01				
	Polyurethan insulation	**0,05**	**0,028**	**1,79**				
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	
		U_W	(W/m^2K)	0,30				
	U_{av}		(W/m^2K)	0,35	$T_{si,min}$		(°C)	17,20

Reference abacus case

Code	PROJECTING CORNER INSULATED INSIDE WITHOUT PILLAR
PC.009	



$$\psi_I = -0.154 + 0.239 \cdot U_W + 0.016 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.971 - 0.175 \cdot U_W (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.003 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.009	0,047	-0,003	0,05	0,00	+0,07	179
V2.PC.009	0,035	-0,037	0,07	0,01		
V3.PC.009	0,050	-0,005	0,06	0,00		
V4.PC.009	0,027	-0,050	0,08	0,01		
V5.PC.009	0,040	-0,017	0,06	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.009	0,876	0,900	-0,02	0,00	-0,02	2
V2.PC.009	0,912	0,925	-0,01	0,00		
V3.PC.009	0,892	0,910	-0,02	0,00		
V4.PC.009	0,928	0,934	-0,01	0,00		
V5.PC.009	0,908	0,919	-0,01	0,00		

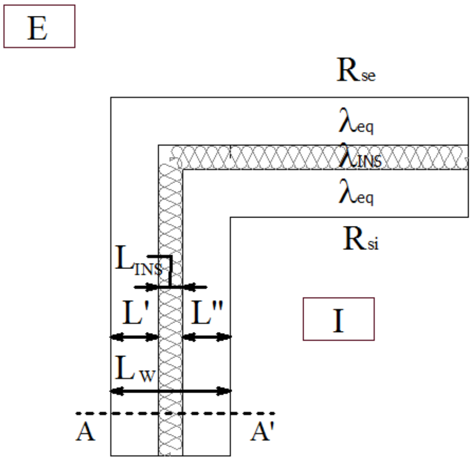
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PC.009	Plasterboard	0,015	0,21	0,07				
	EPS insulation	**0,05**	**0,038**	**1,32**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,41		U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,43	$T_{si,min}$		(°C)	16,90
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V2.PC.009	Plasterboard	0,015	0,21	0,07				
	EPS insulation	**0,1**	**0,038**	**2,63**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,27		U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,28	$T_{si,min}$		(°C)	17,80
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V3.PC.009	Plasterboard	0,015	0,21	0,07				
	EPS insulation	**0,05**	**0,038**	**1,32**				
	Concrete plaster	0,01	1,4	0,01				
	Lightened bricks	**0,3**	**0,23**	**1,30**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,35		U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,37	$T_{si,min}$		(°C)	17,30
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V4.PC.009	Plasterboard	0,015	0,21	0,07				
	Polyurethan insulation	**0,1**	**0,028**	**3,57**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,21		U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,23	$T_{si,min}$		(°C)	18,20
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V5.PC.009	Plasterboard	0,015	0,21	0,07				
	Polyurethan insulation	**0,05**	**0,028**	**1,79**				
	Concrete plaster	0,01	1,4	0,01				
	Lightened bricks	**0,3**	**0,23**	**1,30**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,30		U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,32	$T_{si,min}$		(°C)	17,70

Reference abacus case

Code	PROJECTING CORNER INSULATED IN THE MIDDLE WITHOUT PILLAR
PC.010	



$$\psi_I = 0.110 + 0.051 \cdot U_W - 0.012 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.965 - 0.216 \cdot U_W + 0.018 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.01 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.004 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	(W/mK)^2	(W/mK)	(%)
V1.PC.010	0,074	0,088	-0,01	0,00	-0,02	28
V2.PC.010	0,056	0,078	-0,02	0,00		
V3.PC.010	0,072	0,082	-0,01	0,00		
V4.PC.010	0,046	0,076	-0,03	0,00		
V5.PC.010	0,073	0,077	0,00	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.010	0,892	0,898	-0,01	0,00	±0,01	1
V2.PC.010	0,920	0,919	0,00	0,00		
V3.PC.010	0,892	0,897	0,00	0,00		
V4.PC.010	0,932	0,929	0,00	0,00		
V5.PC.010	0,900	0,907	-0,01	0,00		

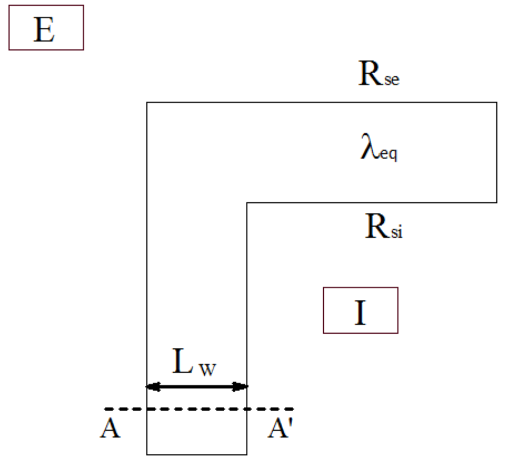
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PC.010	Chalk plaster	0,015	0,35	0,04				
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,06**	**0,038**	**1,58**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**		U_P	(W/m^{2}K)	
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,38	$T_{si,min}$		(°C)	17,30
V2.PC.010	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,11**	**0,038**	**2,89**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,26	$T_{si,min}$		(°C)	18,00
V3.PC.010	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,06**	**0,038**	**1,58**				
	Concrete plaster	0,01	1,4	0,01				
	Lightened bricks	**0,2**	**0,23**	**0,87**		U_P	(W/m^{2}K)	
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,37	$T_{si,min}$		(°C)	17,30
V4.PC.010	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**				
	Alluminium vapour barrie	0,002	0,17	0,01				
	Polyurethan insulation	**0,11**	**0,028**	**3,93**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,19				
	U_{av}		(W/m^{2}K)	0,21	$T_{si,min}$		(°C)	18,30
V5.PC.010	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (L=12cm)	**0,12**	**0,232**	**0,52**				
	Alluminium vapour barrie	0,002	0,17	0,01				
	EPS insulation	**0,07**	**0,038**	**1,84**				
	Concrete plaster	0,01	1,4	0,01				
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**		U_P	(W/m^{2}K)	
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,33	$T_{si,min}$		(°C)	17,50

Reference abacus case

Code	UNINSULATED PROJECTING CORNER WITHOUT PILLAR
PC.011	



$$\psi_I = 0.064 - 0.073 \cdot U_W + 0.385 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.932 - 0.150 \cdot U_W - 0.046 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.011	0,123	0,122	0,00	0,00	±0,01	6
V2.PC.011	0,118	0,114	0,00	0,00		
V3.PC.011	0,106	0,110	0,00	0,00		
V4.PC.011	0,177	0,173	0,00	0,00		
V5.PC.011	0,105	0,117	-0,01	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.011	0,780	0,800	-0,02	0,00	-0,02	3
V2.PC.011	0,756	0,781	-0,03	0,00		
V3.PC.011	0,816	0,823	-0,01	0,00		
V4.PC.011	0,756	0,777	-0,02	0,00		
V5.PC.011	0,784	0,807	-0,02	0,00		

Considerations

Validation cases

V1.PC.011	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (30x30cm)	0,3	0,288	1,04				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,79				
						U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,85	$T_{si,min}$		(°C)	14,50
V2.PC.011	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Brick (25x30cm)	0,25	0,288	0,87				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,91				
						U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,97	$T_{si,min}$		(°C)	13,90
V3.PC.011	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Lightened bricks	0,3	0,23	1,30				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,65				
						U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,71	$T_{si,min}$		(°C)	15,40
V4.PC.011	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04				
	Concrete bricks	0,4	0,45	0,89				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,89				
						U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,98	$T_{si,min}$		(°C)	13,90
V5.PC.011	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Insulating plaster	0,01	0,091	0,11				
	Brick (30x30cm)	0,3	0,288	1,04				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,75				
						U_P	(W/m^{2}K)	
	U_{av}		(W/m^{2}K)	0,80	$T_{si,min}$		(°C)	14,60

4.3.4 Junction between external wall and floor

The fundamental characteristics that change in the stratigraphies of the validation cases are:

- the insulation and brick thickness;
- the insulation and brick thermal conductivity;
- the beam geometry;
- the floor characteristics.

For this type of building junction it has been decided to evaluate the influence of the beam geometry with the cases V4 and the influence of a floor insulated for radiant panels with cases V5.

The MSEP has low values for the most part of the validation reports: it is between 7% and 11% for the linear thermal transmittance and it is between 2% and 11% for the temperature factor at the internal surface. Only FL.001 and FL.003 are characterized by a greater MSEP for the linear thermal transmittance, due to the non-homogeneity of the stratigraphies.

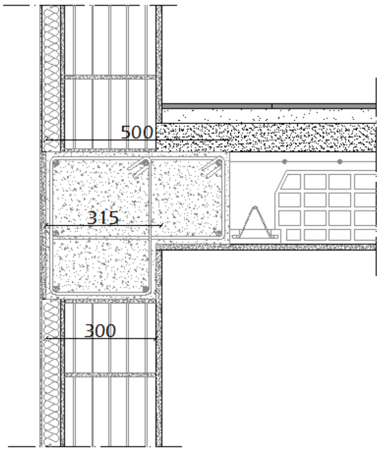
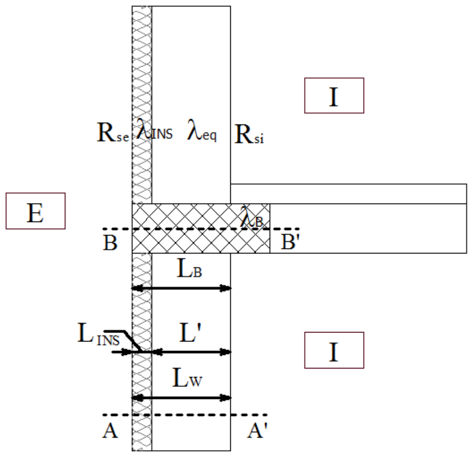


Figure 4.5 - L-shape beam case

Reference abacus case

Code	EXTERNAL WALL INSULATED OUTSIDE WITH FLOOR AND UNINSULATED BEAM
FL.001	



$$\psi_I = 2.068 - 0.056 \cdot U^* - 1.329 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.124 - 0.101 \cdot U_B - 0.010 \cdot \frac{1}{\lambda_{eq}} \ (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.19 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \ (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	(W/mK)^2	(W/mK)	(%)
V1.FL.001	0,849	1,285	-0,44	0,19	-0,44	52
V2.FL.001	0,802	1,118	-0,32	0,10		
V3.FL.001	0,776	1,258	-0,48	0,23		
V4.FL.001	1,072	1,285	-0,21	0,05		
V5.FL.001	0,844	1,285	-0,44	0,20		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.001	0,756	0,807	-0,05	0,00	-0,09	11
V2.FL.001	0,780	0,826	-0,05	0,00		
V3.FL.001	0,776	0,818	-0,04	0,00		
V4.FL.001	0,668	0,807	-0,14	0,02		
V5.FL.001	0,748	0,807	-0,06	0,00		

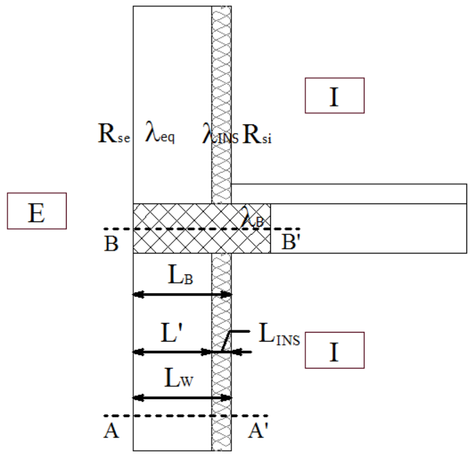
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.FL.001	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,325**	**1,91**	**0,17**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	External plaster	0,005	1,4	0,00
	Alluminium vapour barrie	0,002	0,17	0,01		U_P	(W/m^2K)	2,81
	EPS insulation	**0,05**	**0,038**	**1,32**				
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,87	$T_{si,min}$		(°C)	13,90
V2.FL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,375**	**1,91**	**0,20**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Alluminium vapour barrie	0,002	0,17	0,01
	Concrete plaster	0,01	1,4	0,01	External plaster	0,005	1,4	0,00
	Alluminium vapour barrie	0,002	0,17	0,01		U_P	(W/m^2K)	2,62
	EPS insulation	**0,1**	**0,038**	**2,63**				
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,27				
	U_{av}		(W/m^2K)	0,70	$T_{si,min}$		(°C)	14,50
V3.FL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,375**	**1,91**	**0,20**
	Lightened bricks	**0,3**	**0,23**	**1,30**	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	External plaster	0,005	1,4	0,00
	Alluminium vapour barrie	0,002	0,17	0,01		U_P	(W/m^2K)	2,62
	Polyurethan insulation	**0,05**	**0,028**	**1,79**				
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,30				
	U_{av}		(W/m^2K)	0,72	$T_{si,min}$		(°C)	14,40
V4.FL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,325**	**1,91**	**0,17**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Alluminium vapour barrie	0,002	0,17	0,01
	Concrete plaster	0,01	1,4	0,01	External plaster	0,005	1,4	0,00
	Alluminium vapour barrie	0,002	0,17	0,01		U_P	(W/m^2K)	2,81
	EPS insulation	**0,05**	**0,038**	**1,32**				
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,99	$T_{si,min}$		(°C)	11,70
V5.FL.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,325**	**1,91**	**0,17**
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	External plaster	0,005	1,4	0,00
	Alluminium vapour barrie	0,002	0,17	0,01		U_P	(W/m^2K)	2,81
	EPS insulation	**0,05**	**0,038**	**1,32**				
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,88	$T_{si,min}$		(°C)	13,70

Reference abacus case

Code	EXTERNAL WALL INSULATED INSIDE WITH FLOOR AND UNINSULATED BEAM
FL.002	



$$\psi_I = 1.215 - 0.056 \cdot U^* + 0.025 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.898 - 0.076 \cdot U_B + 0.014 \cdot \frac{1}{\lambda_{eq}} (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.08 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.002	0,814	0,914	-0,10	0,01	±0,09	11
V2.FL.002	0,776	0,748	0,03	0,00		
V3.FL.002	0,746	0,827	-0,08	0,01		
V4.FL.002	0,990	0,914	0,08	0,01		
V5.FL.002	0,834	0,914	-0,08	0,01		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.002	0,724	0,732	-0,01	0,00	-0,04	6
V2.FL.002	0,744	0,746	0,00	0,00		
V3.FL.002	0,748	0,757	-0,01	0,00		
V4.FL.002	0,644	0,732	-0,09	0,01		
V5.FL.002	0,716	0,732	-0,02	0,00		

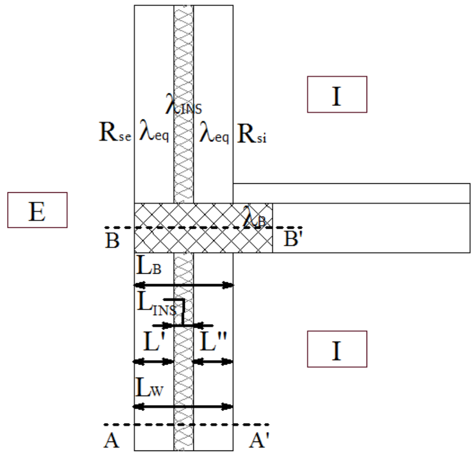
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.FL.002	Plasterboard	0,015	0,21	0,07	Armed concrete	**0,325**	**1,91**	**0,17**
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	2,80
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,85	$T_{si,min}$		(°C)	13,10
V2.FL.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	**0,375**	**1,91**	**0,20**
	EPS insulation	**0,1**	**0,038**	**2,63**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	2,61
	Brick (25x30cm)	**0,25**	**0,288**	0,87				
	Concrete plaster with san	0,015	0,9	**0,02**				
		U_W	(W/m^2K)	0,27				
	U_{av}		(W/m^2K)	0,68	$T_{si,min}$		(°C)	13,60
V3.FL.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	**0,375**	**1,91**	**0,20**
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	2,61
	Lightened bricks	**0,3**	**0,23**	1,30				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,30				
	U_{av}		(W/m^2K)	0,70	$T_{si,min}$		(°C)	13,70
V4.FL.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	**0,325**	**1,91**	**0,17**
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	2,80
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,94	$T_{si,min}$		(°C)	11,10
V5.FL.002	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	**0,325**	**1,91**	**0,17**
	EPS insulation	**0,05**	**0,038**	**1,32**	Concrete plaster with san	0,015	0,9	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	2,80
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,87	$T_{si,min}$		(°C)	12,90

Reference abacus case

Code	EXTERNAL WALL INSULATED IN THE MIDDLE WITH FLOOR AND UNINSULATED BEAM
FL.003	



$$\psi_I = 1.919 - 0.057 \cdot U^* - 1.194 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.093 - 0.100 \cdot U_B - 0.005 \cdot \frac{1}{\lambda_{eq}} (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.20 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.003	0,697	1,147	-0,45	0,20	-0,42	61
V2.FL.003	0,695	1,011	-0,32	0,10		
V3.FL.003	0,696	1,055	-0,36	0,13		
V4.FL.003	0,873	1,147	-0,27	0,08		
V5.FL.003	0,692	1,147	-0,45	0,21		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.003	0,776	0,836	-0,06	0,00	-0,10	13
V2.FL.003	0,780	0,834	-0,05	0,00		
V3.FL.003	0,780	0,833	-0,05	0,00		
V4.FL.003	0,680	0,836	-0,16	0,02		
V5.FL.003	0,764	0,836	-0,07	0,01		

Considerations

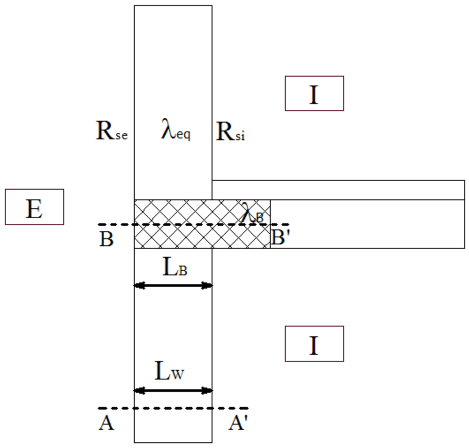
In this case all the real examples presents thermophysical charcteristics that are inside the validity fields provided by the reference report only for the linear thermal transmittance and so the result of this analysis is the validation of only one correlation.

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.FL.003	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster with san	0,015	0,900	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**		U_P	(W/m^{2}K)	2,41
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,71	$T_{si,min}$		(°C)	14,40
V2.FL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,170	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster with san	0,015	0,900	0,02
	EPS insulation	**0,11**	**0,038**	**2,89**		U_P	(W/m^{2}K)	2,41
	Concrete plaster	0,01	1,4	0,01				
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,61	$T_{si,min}$		(°C)	14,50
V3.FL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Brick (L=12cm)	**0,12**	**0,232**	**0,52**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster with san	0,015	0,900	0,02
	Polyurethan insulation	**0,07**	**0,028**	**2,50**		U_P	(W/m^{2}K)	2,41
	Concrete plaster	0,01	1,4	0,01				
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,62	$T_{si,min}$		(°C)	14,50
V4.FL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,170	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster with san	0,015	0,900	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**		U_P	(W/m^{2}K)	2,41
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,81	$T_{si,min}$		(°C)	12,00
V5.FL.003	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster with san	0,015	0,900	0,02
	EPS insulation	**0,06**	**0,038**	**1,58**		U_P	(W/m^{2}K)	2,41
	Concrete plaster	0,01	1,4	0,01				
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^{2}K)	0,34				
	U_{av}		(W/m^{2}K)	0,72	$T_{si,min}$		(°C)	14,10

Reference abacus case

Code	UNINSULATED EXTERNAL WALL WITH FLOOR AND UNINSULATED BEAM
FL.004	



$$\psi_I = 1.322 - 1.457 \cdot L_W + 0.116 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.981 - 0.091 \cdot U_B + 0.005 \cdot \frac{1}{\lambda_{eq}} (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.02 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.004	0,798	0,876	-0,08	0,01	±0,10	12
V2.FL.004	0,746	0,870	-0,12	0,02		
V3.FL.004	0,714	0,748	-0,03	0,00		
V4.FL.004	0,961	0,876	0,09	0,01		
V5.FL.004	0,790	0,881	-0,09	0,01		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.004	0,740	0,739	0,00	0,00	-0,04	5
V2.FL.004	0,744	0,742	0,00	0,00		
V3.FL.004	0,764	0,767	0,00	0,00		
V4.FL.004	0,660	0,739	-0,08	0,01		
V5.FL.004	0,724	0,738	-0,01	0,00		

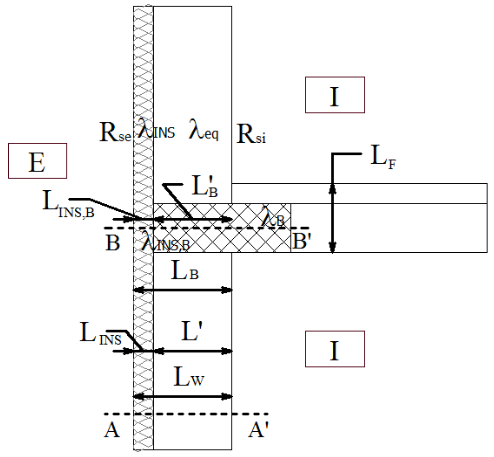
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.FL.004	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,315**	**1,91**	**0,16**
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,84
		U_W	(W/m^{2}K)	0,79				
	U_{av}		(W/m^{2}K)	1,22	$T_{si,min}$		(°C)	13,50
V2.FL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,315**	**1,91**	**0,16**
	Brick (L=20cm)	**0,3**	**0,239**	**1,26**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,84
		U_W	(W/m^{2}K)	0,67				
	U_{av}		(W/m^{2}K)	1,08	$T_{si,min}$		(°C)	13,60
V3.FL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,415**	**1,91**	**0,22**
	Concrete bricks	**0,4**	**0,45**	**0,89**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,48
		U_W	(W/m^{2}K)	0,89				
	U_{av}		(W/m^{2}K)	1,28	$T_{si,min}$		(°C)	14,10
V4.FL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,315**	**1,91**	**0,16**
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,84
		U_W	(W/m^{2}K)	0,79				
	U_{av}		(W/m^{2}K)	1,31	$T_{si,min}$		(°C)	11,50
V5.FL.004	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Insulating plaster	0,01	0,091	0,11	Armed concrete	**0,310**	**1,91**	**0,16**
	Brick (30x30cm)	**0,3**	**0,288**	**1,04**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster with san	0,015	0,9	0,02		U_P	(W/m^{2}K)	2,87
		U_W	(W/m^{2}K)	0,75				
	U_{av}		(W/m^{2}K)	1,17	$T_{si,min}$		(°C)	13,10

Reference abacus case

Code	EXTERNAL WALL INSULATED OUTSIDE WITH FLOOR AND INSULATED BEAM
FL.005	



$$\psi_I = -0.042 + (L_F + 0.089)\cdot U_W + 0.017\cdot\frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m\cdot K}\right)$$

$$f_{Rsi} = 0.966 - 0.130\cdot U_W + 0.039\cdot\lambda_{eq}\,(-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.02 \quad \left(\frac{W}{m\cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.005	0,234	0,215	0,02	0,00	±0,02	9
V2.FL.005	0,133	0,144	-0,01	0,00		
V3.FL.005	0,185	0,174	0,01	0,00		
V4.FL.005	0,241	0,215	0,03	0,00		
V5.FL.005	0,250	0,232	0,02	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.005	0,912	0,924	-0,01	0,00	-0,02	2
V2.FL.005	0,944	0,943	0,00	0,00		
V3.FL.005	0,928	0,936	-0,01	0,00		
V4.FL.005	0,896	0,924	-0,03	0,00		
V5.FL.005	0,900	0,924	-0,02	0,00		

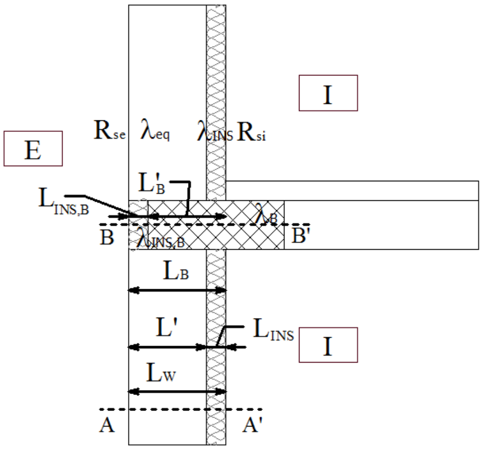
Considerations

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.FL.005	Chalk plaster	0,015	0,35	0,04	Armed concrete	0,275	1,91	0,14
	Brick (25x30cm)	0,25	0,288	0,87	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	EPS insulation	0,050	0,038	1,32
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	0,05	0,038	1,32		U_P	(W/m^{2}K)	0,61
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,54	$T_{si,min}$		(°C)	17,80
V2.FL.005	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	0,275	1,91	0,14
	Brick (25x30cm)	0,25	0,288	0,87	Alluminium vapour barrie	0,002	0,17	0,01
	Concrete plaster	0,01	1,4	0,01	EPS insulation	0,100	0,038	2,63
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	0,1	0,038	2,63		U_P	(W/m^{2}K)	0,34
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,27				
	U_{av}		(W/m^{2}K)	0,34	$T_{si,min}$		(°C)	18,60
V3.FL.005	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	0,325	1,91	0,17
	Lightened bricks	0,3	0,23	1,30	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	Polyurethan insulation	0,050	0,028	1,79
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	Polyurethan insulation	0,05	0,028	1,79		U_P	(W/m^{2}K)	0,47
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,30				
	U_{av}		(W/m^{2}K)	0,40	$T_{si,min}$		(°C)	18,20
V4.FL.005	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	0,275	1,91	0,14
	Brick (25x30cm)	0,25	0,288	0,87	Alluminium vapour barrie	0,002	0,17	0,01
	Concrete plaster	0,01	1,4	0,01	EPS insulation	0,050	0,038	1,32
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	0,05	0,038	1,32		U_P	(W/m^{2}K)	0,61
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,54	$T_{si,min}$		(°C)	17,40
V5.FL.005	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	0,275	1,91	0,14
	Brick (25x30cm)	0,25	0,288	0,87	Alluminium vapour barrie	0,002	0,170	0,01
	Concrete plaster	0,01	1,4	0,01	EPS insulation	0,050	0,038	1,32
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	0,05	0,038	1,32		U_P	(W/m^{2}K)	0,61
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,55	$T_{si,min}$		(°C)	17,50

Reference abacus case

Code	EXTERNAL WALL INSULATED INSIDE WITH FLOOR AND INSULATED BEAM
FL.006	



$$\psi_I = -0.076 + 0.875 \cdot U^* - 0.211 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.939 - 0.153 \cdot U_W - 0.152 \cdot \lambda_{eq} (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.006	0,492	0,526	-0,03	0,00	-0,03	7
V2.FL.006	0,503	1,225	-0,72	0,52		
V3.FL.006	0,347	-0,197	0,54	0,30		
V4.FL.006	0,494	0,526	-0,03	0,00		
V5.FL.006	0,521	0,526	0,00	0,00		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.006	0,824	0,831	-0,01	0,00	±0,02	2
V2.FL.006	0,832	0,853	-0,02	0,00		
V3.FL.006	0,872	0,856	0,02	0,00		
V4.FL.006	0,812	0,831	-0,02	0,00		
V5.FL.006	0,820	0,831	-0,01	0,00		

Considerations

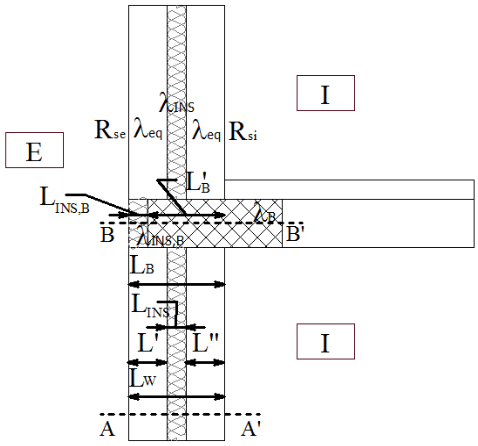
V2.FL.006 and V3.FL.006 present a U* that is outside of the validity field provided by the reference report. The difference between these values and the minimum of the allowed range is low, but the generated error is very significant. As a consequence, these values have been excluded by the evaluation of the MSE for the linear thermal transmittance.

Validation cases

V1.FL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	0,273	1,91	0,14
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,038	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^2K)	0,61
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,67	$T_{si,min}$		(°C)	15,60
V2.FL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	0,273	1,91	0,14
	EPS insulation	0,1	0,038	2,63	EPS insulation	0,05	0,038	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,900	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^2K)	0,61
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,27				
	U_{av}		(W/m^2K)	0,54	$T_{si,min}$		(°C)	15,80
V3.FL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	0,323	1,91	0,17
	Polyurethan insulation	0,05	0,028	1,79	Polyurethan insulation	0,1	0,028	3,57
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Lightened bricks	0,3	0,23	1,30		U_P	(W/m^2K)	0,25
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,30				
	U_{av}		(W/m^2K)	0,49	$T_{si,min}$		(°C)	16,80
V4.FL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	0,273	1,91	0,14
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,038	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,900	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^2K)	0,61
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,68	$T_{si,min}$		(°C)	15,30
V5.FL.006	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Plasterboard	0,015	0,21	0,07	Armed concrete	0,273	1,91	0,14
	EPS insulation	0,05	0,038	1,32	EPS insulation	0,05	0,038	1,32
	Concrete plaster	0,01	1,4	0,01	Concrete plaster with san	0,015	0,9	0,02
	Brick (25x30cm)	0,25	0,288	0,87		U_P	(W/m^2K)	0,61
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,41				
	U_{av}		(W/m^2K)	0,70	$T_{si,min}$		(°C)	15,50

Reference abacus case

Code	EXTERNAL WALL INSULATED IN THE MIDDLE WITH FLOOR AND INSULATED BEAM
FL.007	



$$\psi_I = -0.290 + 1.015 \cdot U^* - 0.219 \cdot \frac{1}{\lambda_{eq}} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.949 - 0.167 \cdot U_W - 0.033 \cdot \lambda_{eq} \, (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.12 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the mean square error by real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_{Ψ}	$MSEP_{\Psi}$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.FL.007	0,439	0,764	-0,325	0,11	0,400	91
V2.FL.007	0,416	1,481	-1,065	1,13		
V3.FL.007	0,323	-0,103	0,426	0,18		
V4.FL.007	0,462	0,764	-0,303	0,09		
V5.FL.007	0,444	0,764	-0,320	0,10		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.FL.007	0,848	0,883	-0,035	0,00	0,046	5
V2.FL.007	0,864	0,901	-0,037	0,00		
V3.FL.007	0,892	0,900	-0,008	0,00		
V4.FL.007	0,820	0,883	-0,063	0,00		
V5.FL.007	0,840	0,883	-0,043	0,00		

Considerations

In this case all the real examples presents thermophysical charcteristics that are inside the validity fields provided by the reference report only for the temperature factor at the internal surface and so the result of this analysis is the validation of only one correlation.

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.FL.007	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,355**	**1,91**	**0,19**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	**0,05**	**0,04**	**1,32**
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	0,59
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,34				
	U_{av}		(W/m^2K)	0,57	$T_{si,min}$		(°C)	16,20
V2.FL.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,305**	**1,91**	**0,16**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,170	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	**0,05**	**0,04**	**1,32**
	EPS insulation	**0,11**	**0,038**	**2,89**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	0,60
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,24				
	U_{av}		(W/m^2K)	0,46	$T_{si,min}$		(°C)	16,60
V3.FL.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,345**	**1,91**	**0,18**
	Brick (L=12cm)	**0,12**	**0,232**	**0,52**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Polyurethan insulation	**0,10**	**0,03**	**3,57**
	Polyurethan insulation	**0,07**	**0,028**	**2,50**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	0,25
	Brick (L=20cm)	**0,2**	**0,239**	**0,84**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,24				
	U_{av}		(W/m^2K)	0,42	$T_{si,min}$		(°C)	17,30
V4.FL.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,355**	**1,91**	**0,19**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,170	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	**0,05**	**0,04**	**1,32**
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	0,59
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,34				
	U_{av}		(W/m^2K)	0,59	$T_{si,min}$		(°C)	15,50
V5.FL.007	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	BEAM	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Armed concrete	**0,355**	**1,91**	**0,19**
	Brick (L=8cm)	**0,08**	**0,3**	**0,27**	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	EPS insulation	**0,05**	**0,04**	**1,32**
	EPS insulation	**0,06**	**0,038**	**1,58**	Concrete plaster with san	0,015	0,900	0,02
	Concrete plaster	0,01	1,4	0,01		U_P	(W/m^2K)	0,59
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**				
	Concrete plaster with san	0,015	0,9	0,02				
		U_W	(W/m^2K)	0,34				
	U_{av}		(W/m^2K)	0,58	$T_{si,min}$		(°C)	16,00

5 CONCLUSIONS

The study done for this thesis starts from the CESTEC-ANCE thermal bridges abacus, in order to complete and to validate it.

This reference abacus provides reports with some correlations about the linear thermal transmittance of several schematizations of thermal bridges. These allow the loss of heat flow rate evaluation because of the thermal bridge. The study described in this document tries to evaluate the second consequence of the thermal bridge: the condensation. For this purpose, it has been necessary to develop new correlations, which define the temperature factor at the internal surface. This factor allows the superficial condensation evaluation.

The second part of the analysis explained in this document is a validation of some abacus reports in order to determine if their correlations can be applied on real building junctions. The first step for the validation has been the setting up of some simulations on real building junctions and the calculation of the linear thermal transmittance and the temperature factor at the internal surface through their outputs. Then, it has been possible to obtain the mean square error given by these results with reference to the abacus correlation.

The criteria used to choose the correlation, which better represents the temperature factor at the internal surface for the schematization of thermal bridge in question, have been: the confidence interval amplitude, the use of parameters which are simple to obtain and the use of the same parameters for similar cases. The correlations provided by the reports show that it has been likely to apply all these criteria together. For example, taking into consideration the reports about the junctions between external wall and pillar, it is possible to see that the correlations of the junctions with an un-insulated pillar are based on the same parameters, as the junctions with an insulated pillar. However, these groups of correlations based on the same parameters present a low value of the confidence interval, which is usually between 0.01 and 0.06. The confidence interval, as explained before in chapter **2.6**, represents the distance from the correlation in which it is possible to find 95% of the values expressed by the correlation itself. If the confidence interval is equal to 0.01, as to 0.06, it means that there is a good relation among the variables indicated in the correlation.

The validation shows that the introduction of non-homogeneous elements often brings the simulations results out of the confidence interval given by the reference abacus. The MSEP (mean square error percentage) obtained is often less than 30% and so the schematizations used in this analysis can approximately represent real cases.

For the temperature factor at the internal surface the MSEP is very low (the maximum is 11%) and so its correlations, given by the reference abacus, are a good representation of the reality.

A possible development for the future could be the study of correlations about the linear thermal transmittance and the temperature factor at the internal surface for other schematizations of thermal bridge, such as:

- ground floors;
- vertical sections of junctions between external walls and windows;
- microventilated external walls.

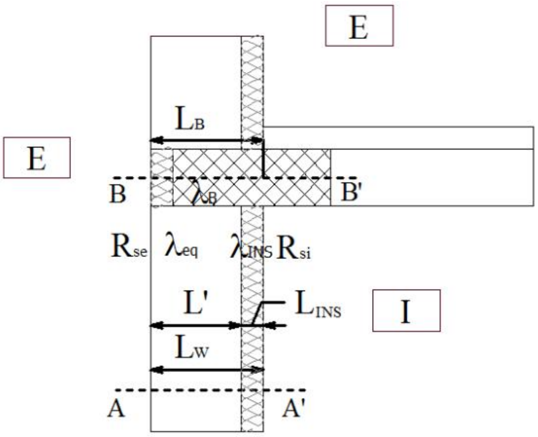


Figure 5.2 - External wall insulated inside with un-insulated plane roof, insulated beam and insulated parapet

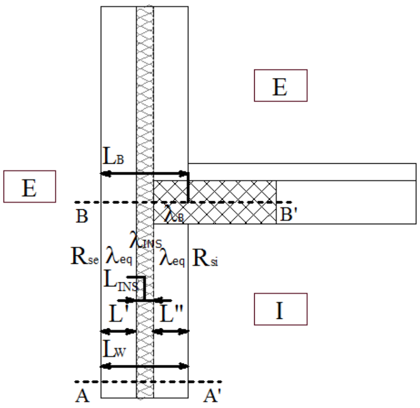


Figure 5.1 – External wall insulated in the middle with floor and insulated beam

Another development could be the addition of other schematization to the families already studied, such as: junction between external wall insulated inside and (insulated or un-insulated) plane roof with insulated beam and insulated parapet (**Figure 5.1**)or junction between external wall insulated in the middle and floor with insulated beam (**Figure 5.2**).

Other aspects to develop in the future are the evaluation of the correlations of the temperature factor at the internal surface for ridges and compluviums. These haven't been calculated because the adopted geometrical approach have not requested simulations on them.

The validation can be amplified studying the other abacus families and increasing the evaluations on the cases with a significant MSEP with more simulations on real building junctions or studying the same simulations with external dimensions in order to evaluate if the errors generated by the two dimensions are the same.

The cases of junctions between external wall and pillar totally insulated inside or outside could be studied through FLUENT to see if the mean square error is due to the building junction itself or to the relative error between the two programs.

In the end, another study could be the application of the abacus correlations on real buildings.

6 ANNEXES

6.1 ANNEX A: EC of some correlations of CESTEC-ANCE thermal bridges abacus

With a detailed analysis during the development of the correlations about the temperature factor at the internal surface and during the validation, it has been possible to point out some mistakes in the correlations about the linear thermal transmittance.

The reports that have been corrected are:

- CC.007;
- PC.007;
- PR.009;
- PR.013;
- PR.018;
- FL.005.

CC.007 and PC.007 correlations had been developed previously also on U_y results. U_y is the schematization in which the insulation of the wall and that one of the pillar communicate. This aspect add another degree of freedom to the building junction and so it should not be considered during the development of the correlation. The correlations indicated in the previous reports don’t consider U_y. The same approach had already been used in the correlations about junctions between external wall and pillar.

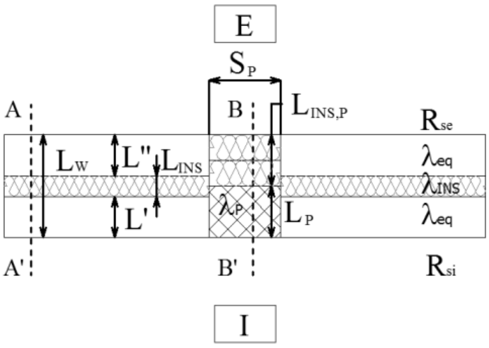


Figure 6.1 - Uy schematization

In PR.009, PR.013 and PR.018 there was a problem in the thermal transmittance of the building elements (U_W and U_B) used to develop the correlation: the value was always the same despite the difference in the brick density and in the wall thickness.

FL.005 gave linear thermal transmittance values too high, considering that this schematization is totally insulated outside. Using MATLAB, it has been possible to verify the correlation and to see that there was an error in the order of magnitude of a coefficient.

6.2 ANNEX B: Thermal characteristics of the adopted stratigraphies

Wall characterized by a brick densities equal to 1200 kg /m^3 and a thermal conductivity equal to 0.54 W/m*K

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.050	37	0.040	1.250
2	Brick	0.250	1200	0.540	0.463
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**1.883**
	Total thermal transmittance [W/m^{2}K]				**0.531**
Total thickness	**0.30**				

U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.150	37	0.040	3.750
2	Brick	0.450	1200	0.540	0.833
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**4.753**
	Total thermal transmittance [W/m^{2}K]				**0.210**
Total thickness	**0.60**				

U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.100	37	0.040	2.500
2	Brick	0.400	1200	0.540	0.741
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**3.411**
	Total thermal transmittance [W/m^{2}K]				**0.293**
Total thickness	**0.50**				

Table 6.1 - Thermal transmittance of insulated walls with a brick density equal to 1200 kg/m^3

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.250	1200	0.540	0.463
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**0.633**
	Total thermal transmittance [W/m^{2}K]				**1.580**
Total thickness	**0.25**				

U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.450	1200	0.540	0.833
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**1.003**
	Total thermal transmittance [W/m^{2}K]				**0.997**
Total thickness	**0.45**				

U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.400	1200	0.540	0.741
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**0.911**
	Total thermal transmittance [W/m^{2}K]				**1.098**
Total thickness	**0.40**				

Table 6.2 - Thermal transmittance of un-insulated walls with a brick density equal to 1200 kg/m^3

Wall characterized by a brick densities equal to 1800 kg /m^3 and a thermal conductivity equal to 0.81 W/m*K

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Insulation	0.050	37	0.040	1.250
2	Brick	0.250	1800	0.810	0.309
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				1.729
	Total thermal transmittance [W/m^2K]				0.578
Total thickness	0.30				

U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Insulation	0.150	37	0.040	3.750
2	Brick	0.450	1800	0.810	0.556
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				4.476
	Total thermal transmittance [W/m^2K]				0.223
Total thickness	0.60				

U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Insulation	0.100	37	0.040	2.500
2	Brick	0.400	1800	0.810	0.494
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				3.164
	Total thermal transmittance [W/m^2K]				0.316
Total thickness	0.50				

Table 6.3 - Thermal transmittance of insulated walls with a brick density equal to 1800 kg/m^3

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.250	1800	0.810	0.309
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**0.479**
	Total thermal transmittance [W/m^{2}K]				**2.089**
Total thickness	**0.25**				

U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.450	1800	0.810	0.556
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**0.726**
	Total thermal transmittance [W/m^{2}K]				**1.378**
Total thickness	**0.45**				

U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Brick	0.400	1800	0.810	0.494
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**0.664**
	Total thermal transmittance [W/m^{2}K]				**1.506**
Total thickness	**0.40**				

Table 6.4 -Thermal transmittance of un-insulated walls with a brick density equal to 1800 kg/m^3

Wall characterized by a brick densities equal to 760 kg /m^3 and a thermal conductivity equal to 0.23 W/m*K

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.050	37	0.040	1.250
2	Brick	0.250	760	0.230	1.087
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**2.507**
	Total thermal transmittance [W/m^{2}K]				**0.399**
Total thickness	0.30				

U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.150	37	0.040	3.750
2	Brick	0.450	760	0.230	1.957
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**5.877**
	Total thermal transmittance [W/m^{2}K]				**0.170**
Total thickness	0.60				

U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^{2}K/W]
E	Rse				0.040
1	Insulation	0.100	37	0.040	2.500
2	Brick	0.400	760	0.230	1.739
I	Rsi				0.130
	Total thermal resistance [m^{2}K/W]				**4.409**
	Total thermal transmittance [W/m^{2}K]				**0.227**
Total thickness	0.50				

Table 6.5 - Thermal transmittance of insulated walls with a brick density equal to 760 kg/m^3

U_{max}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Brick	0.250	760	0.230	1.087
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				**1.257**
	Total thermal transmittance [W/m^2K]				**0.796**
Total thickness	**0.25**				

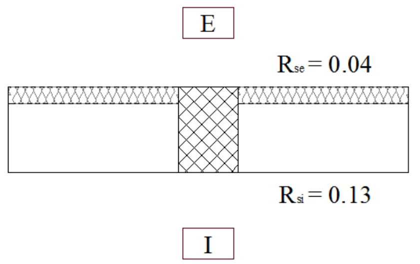
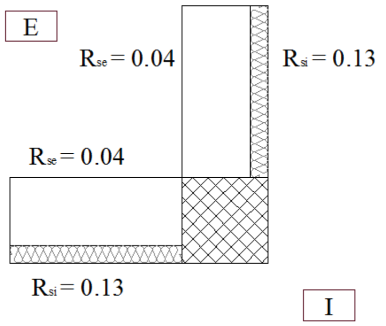
U_{min}					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Brick	0.450	760	0.230	1.957
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				**2.127**
	Total thermal transmittance [W/m^2K]				**0.470**
Total thickness	**0.45**				

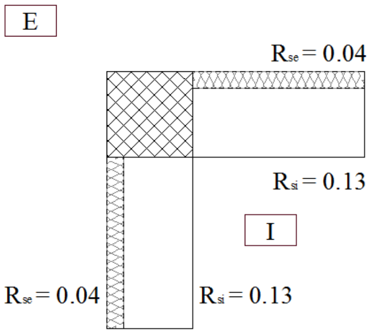
U_m					
N	STRATIGRAPHY	Thickness [m]	Density [kg/m^3]	Thermal conductivity [W/mK]	Sect A-A' [m^2K/W]
E	Rse				0.040
1	Brick	0.400	760	0.230	1.739
I	Rsi				0.130
	Total thermal resistance [m^2K/W]				**1.909**
	Total thermal transmittance [W/m^2K]				**0.524**
Total thickness	**0.40**				

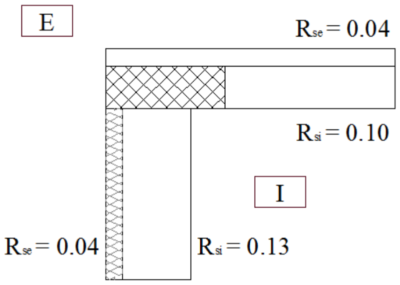
Table 6.6 -Thermal transmittance of un-insulated walls with a brick density equal to 760 kg/m^3

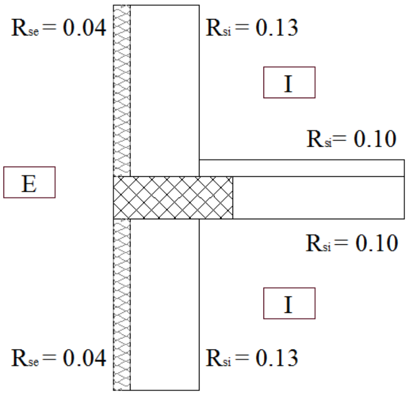
6.3 ANNEX C: Surface resistances applied in the simulations

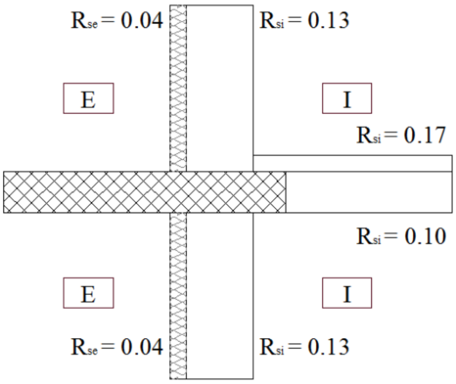
This annex resumes the surface resistance values adopted in the simulations.

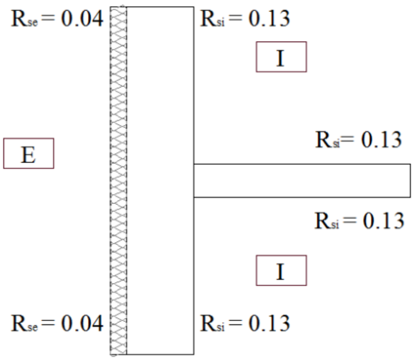
<table>
<tr><th rowspan="2">TB</th><th colspan="2">HORIZONTAL SURFACE</th><th colspan="2">VERTICAL SURFACE</th></tr>
<tr><th>R_{si}</th><th>R_{se}</th><th>R_{si}</th><th>R_{se}</th></tr>
<tr><td>From PIL.001 to PIL.008</td><td>0.13</td><td>0.04</td><td></td><td></td></tr>
<tr><td><u>External wall with pillar</u></td><td colspan="4">HORIZONTAL SECTION
 </td></tr>
<tr><th rowspan="2">TB</th><th colspan="2">HORIZONTAL SURFACE</th><th colspan="2">VERTICAL SURFACE</th></tr>
<tr><th>R_{si}</th><th>R_{se}</th><th>R_{si}</th><th>R_{se}</th></tr>
<tr><td>From CC.001 to CC.011</td><td>0.13</td><td>0.04</td><td></td><td></td></tr>
<tr><td><u>Concave corners with or without pillar</u></td><td colspan="4">HORIZONTAL SECTION
 </td></tr>
</table>

TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From PC.001 to PC.011	0.13	0.04		
Projecting corners with or without pillar	HORIZONTAL SECTION 			

TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From PR.001 to PR.018	0.13	0.04	0.10	0.04
External wall with plane roof	VERTICAL SECTION 			

TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From FL.001 to FL.007	0.13	0.04	0.10	0.04
External wall with floor	VERTICAL SECTION 			

TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From BALC.001 to BALC.007	0.13	0.04	0.10	0.04
External wall with balcony	VERTICAL SECTION  			

TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From INT.001 to INT.004	0.13	0.04		
External and internal walls	HORIZONTAL SECTION  			

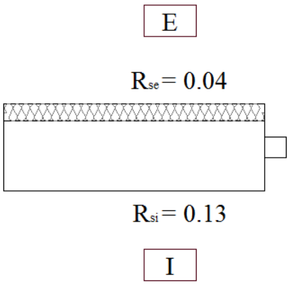
TB	HORIZONTAL SURFACE		VERTICAL SURFACE	
	R_{si}	R_{se}	R_{si}	R_{se}
From WIND.001 to WIND.018	0.13	0.04		
External wall with windows	HORIZONTAL SECTION  			

Table 6.7 - Summary of the internal and external surface resistance adopted in simulations

6.4 ANNEX D: Dimensions used in the simulations

This annex resumes the dimensions used in the simulations.

<u>External wall with pillar</u>

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	PILLAR THICKNESS	PILLAR WIDTH	INSULATION THICKNESS (PILLAR)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]
PIL.001	0.3 - 0.6	1	1	0.05 - 0.15	0.3 - 0.6	0.3-0.5	-
PIL.002	0.3 - 0.6	1	1	0.05 - 0.15	0.3 - 0.6	0.3-0.5	-
PIL.003	0.3 - 0.6	1	1	0.05 - 0.15	0.3 - 0.6	0.3-0.5	-
PIL.004	0.25 - 0.45	1	1	-	0.25 - 0.45	0.3-0.5	-
PIL.005	0.3 - 0.6	1	1	0.05 - 0.15	0.25 - 0.45	0.3-0.5	0.05 - 0.15
PIL.006	0.3 - 0.6	1	1	0.05 - 0.15	0.25 - 0.45	0.3-0.5	0.05 - 0.15
PIL.007	0.3 - 0.6	1	1	0.05 - 0.15	0.25 - 0.45	0.3-0.5	0.05 - 0.15
PIL.008	0.3 - 0.6	1	1	0.05 - 0.15	0.25 - 0.45	0.3-0.5	0.05 - 0.15

Table 6.8 - Dimensions for junction between external wall and pillar

<u>Concave corners with or without pillar</u>

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	PILLAR THICKNESS	PILLAR WIDTH	INSULATION THICKNESS (PILLAR)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]
CONCAVE CORNERS WITH PILLAR							
CC.001	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
CC.002	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
CC.003	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
CC.004	0.25 - 0.45	1.25 - 1.45	1	-	0.25 - 0.45	0.25 - 0.45	-
CC.005	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
CC.006	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
CC.007	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
CONCAVE CORNERS WITHOUT PILLAR							
CC.008	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	-	-	-
CC.009	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	-	-	-
CC.010	0.3 - 0.6	1.3 - 1.6	1	0.05 - 0.15	-	-	-
CC.011	0.25 - 0.45	1.25 - 1.45	1	-	-	-	-

Table 6.9 - Dimension for concave corners

Projecting corners with or without pillar

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	PILLAR THICKNESS	PILLAR WIDTH	INSULATION THICKNESS (PILLAR)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]
PROJECTING CORNERS WITH PILLAR							
PC.001	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
PC.002	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
PC.003	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.3 - 0.6	0.3 - 0.6	-
PC.004	0.25 - 0.45	1	1.25 - 1.45	-	0.25 - 0.45	0.25 - 0.45	-
PC.005	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
PC.006	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
PC.007	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	0.25 - 0.45	0.25 - 0.45	0.05 - 0.15
PROJECTING CORNERS WITH PILLAR							
PC.008	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	-	-	-
PC.009	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	-	-	-
PC.010	0.3 - 0.6	1	1.3 - 1.6	0.05 - 0.15	-	-	-
PC.011	0.25 - 0.45	1	1.25 - 1.45	-	-	-	-

Table 6.10 - Dimension for projecting corners

External wall with plane roof

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	BEAM THICKNESS	BEAM WIDTH	SLAB THICKNESS	INS. THICKNESS (FLOOR)	INS. THICKNESS (BEAM)	FLOOR THICKNESS	BEAM WIDTH (internal dimensions)	BEAM WIDTH (external dimensions)	PARAPET HEIGHT	INS. THICKNESS (PARAPET)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
PR.001	0.3 - 0.6	1	1.35	0.05 - 0.15	0.25	0.7	0.1	-	-	0.35	1.1 - 1.4	1.7	-	-
PR.002	0.3 - 0.6	1	1.35	0.05 - 0.15	0.25	0.7	0.1	-	-	0.35	1.1 - 1.4	1.7	-	-
PR.003	0.3 - 0.6	1	1.35	0.05 - 0.15	0.25	0.7	0.1	-	-	0.35	1.1 - 1.4	1.7	-	-
PR.004	0.25 - 0.45	1	1.35	-	0.25	0.7	0.1	-	-	0.35	1.25 - 1.45	1.7	-	-
PR.005	0.3 - 0.6	1	1.45	0.05 - 0.15	0.25	0.7	0.1	0.1	-	0.45	1.1 - 1.4	1.7	-	-
PR.006	0.3 - 0.6	1	1.45	0.05 - 0.15	0.25	0.7	0.1	0.1	-	0.45	1.1 - 1.4	1.7	-	-
PR.007	0.3 - 0.6	1	1.45	0.05 - 0.15	0.25	0.7	0.1	0.1	-	0.45	1.1 - 1.4	1.7	-	-
PR.008	0.25 - 0.45	1	1.45	-	0.25	0.7	0.1	0.1	-	0.45	1.25 - 1.45	1.7	-	-
PR.009	0.3 - 0.6	1	1.45	0.05 - 0.15	0.25	0.7	0.1	0.1	0.05 - 0.15	0.45	1.25 - 1.45	1.75 - 1.85	-	-
PR.010	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	-	0.05 - 0.15	0.35	1.25 - 1.45	1.75 - 1.85	0.5	0.05 - 0.15
PR.011	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	0.1	0.05 - 0.15	0.45	1.25 - 1.45	1.75 - 1.85	0.5	0.05 - 0.15
PR.012	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	-	-	0.35	1.1 - 1.4	1.7	0.5	0.05 - 0.15
PR.013	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	0.1	-	0.45	1.1 - 1.4	1.7	0.5	0.05 - 0.15
PR.014	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	-	0.05 - 0.15	0.35	1.475 - 1.575	1.875 - 2.075	0.5	0.05 - 0.15
PR.015	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	0.1	0.05 - 0.15	0.45	1.475 - 1.575	1.875 - 2.075	0.5	0.05 - 0.15
PR.016	0.25 - 0.45	1	1.75	-	0.25	0.7	0.1	-	-	0.35	1.25 - 1.45	1.7	0.5	-
PR.017	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	-	-	0.35	1.1 - 1.4	1.7	0.5	0.05 - 0.15
PR.018	0.3 - 0.6	1	1.75	0.05 - 0.15	0.25	0.7	0.1	0.1	-	0.45	1.1 - 1.4	1.7	0.5	0.05 - 0.15

Table 6.11 - Dimension for junction between external wall and plane roof

External wall with floor

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	BEAM THICKNESS	BEAM WIDTH	SLAB THICKNESS	FLOOR THICKNESS	INSULATION THICKNESS (BEAM)	BEAM WIDTH (internal dimensions)	BEAM WIDTH (external dimensions)	PARAPET HEIGHT	INSULATION THICKNESS (PARAPET)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
FL.001	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	-	1.1 - 1.4	1.7		
FL.002	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	-	1.1 - 1.4	1.7		
FL.003	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	-	1.1 - 1.4	1.7		
FL.004	0.25 - 0.45	1	2.25	-	0.25	0.7	0.1	0.35	-	1.25 - 1.45	1.7		
FL.005	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	0.05 - 0.15	1.25 - 1.45	1.75 - 1.85		
FL.006	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	0.05 - 0.15	1.25 - 1.45	1.75 - 1.85		
FL.007	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	0.05 - 0.15	1.25 - 1.45	1.75 - 1.85		

Table 6.12 - Dimension for junction between external wall and floor

External wall with balcony

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	BEAM THICKNESS	BEAM WIDTH	SLAB THICKNESS	FLOOR THICKNESS	BEAM WIDTH (internal dimensions)	BEAM WIDTH (external dimensions)	BALCONY THICKNESS	BALCONY WIDTH	INSULATION THICKNESS (BALCONY)
	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
BALC.001	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	-
BALC.002	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	-
BALC.003	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	-
BALC.004	0.25 - 0.45	1	2.25	-	0.25	0.7	0.1	0.35	1.25 - 1.45	1.7	0.25	1	-
BALC.005	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	0.05
BALC.006	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	0.05
BALC.007	0.3 - 0.6	1	2.25	0.05 - 0.15	0.25	0.7	0.1	0.35	1.1 - 1.4	1.7	0.25	1	0.05

Table 6.13 - Dimension for junction between external wall and balcony

External and internal walls

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	INTERNAL WALL THICKNESS	INTERNAL WALL LENGTH
	[m]	[m]	[m]	[m]	[m]	[m]
INT.001	0.3 - 0.6	1	2.1	0.05 - 0.15	0.1	1
INT.002	0.3 - 0.6	1	2.1	0.05 - 0.15	0.1	1
INT.003	0.3 - 0.6	1	2.1	0.05 - 0.15	0.1	1
INT.004	0.25 - 0.45	1	2.1	-	0.1	1

Table 6.14 - Dimension for junction between external and internal walls

External wall with windows

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	FRAME THICKNESS	FRAME WIDTH	LINTEL THICKNESS	LINTEL WIDTH
	[m]	[m]	[m]	[m]	[m]	[m]	[m]	[m]
WIND.001	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.002	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.003	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.004	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.005	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	0.3 - 0.6	0.2
WIND.006	0.25 - 0.45	1	1	-	0.06	0.06	-	-
WIND.007	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.008	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.009	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.010	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.011	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	0.3 - 0.6	0.2
WIND.012	0.25 - 0.45	1	1	-	0.06	0.06	-	-
WIND.013	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.014	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.015	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.016	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	-	-
WIND.017	0.3 - 0.6	1	1	0.05 - 0.15	0.06	0.06	0.3 - 0.6	0.2
WIND.018	0.25 - 0.45	1	1	-	0.06	0.06	-	-

Table 6.15 - Dimension for junction between external wall and windows

Ridges and compluviums

TB	WALL THICKNESS	WALL LENGTH (internal dimensions)	WALL LENGTH (external dimensions)	INSULATION THICKNESS (WALL)	ROOF INCLINATION FROM THE HORIZONTAL
RID.001	everyone	everyone	everyone	everyone	≤ 30 °
RID.002	everyone	everyone	everyone	everyone	≤ 30 °
RID.003	everyone	everyone	everyone	everyone	≤ 30 °
COM.001	everyone	everyone	everyone	everyone	≤ 30 °
COM.002	everyone	everyone	everyone	everyone	≤ 30 °
COM.003	everyone	everyone	everyone	everyone	≤ 30 °

Table 6.16 - Dimension for ridges and compluviums

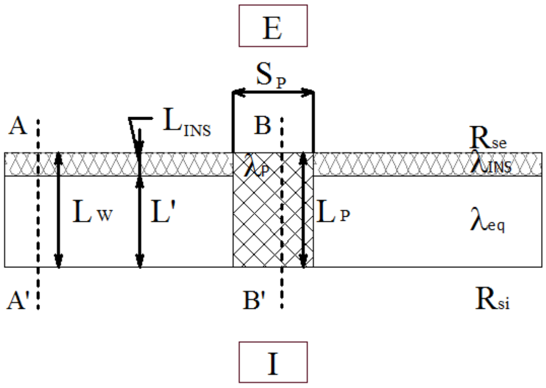
6.5 ANNEX E: Reports with nine validation cases

For the cases of junction between an external wall insulated outside and an un-insulated pillar (PIL.001) and the projecting corner with an external wall insulated outside and an un-insulated pillar (PC.001) it has been decide to execute more simulations on real examples in order to verify the influence of the number of simulation on the final error.

For the first case the reports are the following ones:

Reference abacus case

Code	EXTERNAL WALL INSULATED OUTSIDE WITH UNINSULATED PILLAR
PIL.001	



$$\psi_I = 0.695 - 0.064 \cdot U^* + 2.231 \cdot S_P \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 1.149 - 0.152 \cdot S_P - 0.143 \cdot U_P (-)$$

Reference correlation precision

$$IC_I^{95\%} = \pm 0.09 \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.04 \ (-)$$

Evaluation of the root mean square error through real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PIL.001	1,036	1,193	-0,16	0,02	±0,17	16
V2.PIL.001	1,087	1,116	-0,03	0,00		
V3.PIL.001	1,056	1,047	0,01	0,00		
V4.PIL.001	1,101	0,916	0,18	0,03		
V5.PIL.001	0,811	0,970	-0,16	0,03		
V6.PIL.001	1,176	1,414	-0,24	0,06		
V7.PIL.001	1,031	0,910	0,12	0,01		
V8.PIL.001	0,876	1,256	-0,38	0,14		
V9.PIL.001	0,926	1,131	-0,21	0,04		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PIL.001	0,692	0,724	-0,03	0,00	-0,03	4
V2.PIL.001	0,696	0,724	-0,03	0,00		
V3.PIL.001	0,712	0,741	-0,03	0,00		
V4.PIL.001	0,716	0,741	-0,02	0,00		
V5.PIL.001	0,708	0,739	-0,03	0,00		
V6.PIL.001	0,708	0,731	-0,02	0,00		
V7.PIL.001	0,676	0,724	-0,05	0,00		
V8.PIL.001	0,764	0,785	-0,02	0,00		
V9.PIL.001	0,780	0,796	-0,02	0,00		

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V1.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**2,55**
		U_W	(W/m^2K)	**0,41**				
	U_{av}		(W/m^2K)	**0,85**	$T_{si,min}$		(°C)	**12,30**
V2.PIL.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**2,55**
		U_W	(W/m^2K)	**0,35**				
	U_{av}		(W/m^2K)	**0,80**	$T_{si,min}$		(°C)	**12,40**
V3.PIL.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^2K)	**2,43**
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	**0,29**				
	U_{av}		(W/m^2K)	**0,73**	$T_{si,min}$		(°C)	**12,80**
V4.PIL.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (S_P=40cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	Polyurethan insulation	**0,09**	**0,028**	**3,21**		U_P	(W/m^2K)	**2,43**
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	**0,23**				
	U_{av}		(W/m^2K)	**0,69**	$T_{si,min}$		(°C)	**12,90**
V5.PIL.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (S_P=30cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**2,55**
		U_W	(W/m^2K)	**0,41**				
	U_{av}		(W/m^2K)	**0,77**	$T_{si,min}$		(°C)	**12,70**

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=50cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V6.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,35**	**1,91**	**0,18**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,39
		U_W	(W/m^{2}K)	0,39				
	U_{av}		(W/m^{2}K)	0,86	$T_{si,min}$		(°C)	12,70
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V7.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	GASBETON bricks	**0,25**	**0,096**	**2,60**	Armed concrete	**0,3**	**1,91**	**0,16**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,55
		U_W	(W/m^{2}K)	0,24				
	U_{av}		(W/m^{2}K)	0,67	$T_{si,min}$		(°C)	11,90
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V8.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Concrete bricks	**0,4**	**0,45**	**0,89**	Armed concrete	**0,45**	**1,91**	**0,24**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,01	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,005	1,4	0,00
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,12
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,78	$T_{si,min}$		(°C)	14,10
	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (S_P=40cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V9.PIL.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,015	0,35	0,04
	Concrete bricks	**0,4**	**0,45**	**0,89**	Armed concrete	**0,5**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,002	0,17	0,01
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,005	1,4	0,00
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^{2}K)	2,04
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,67	$T_{si,min}$		(°C)	14,50

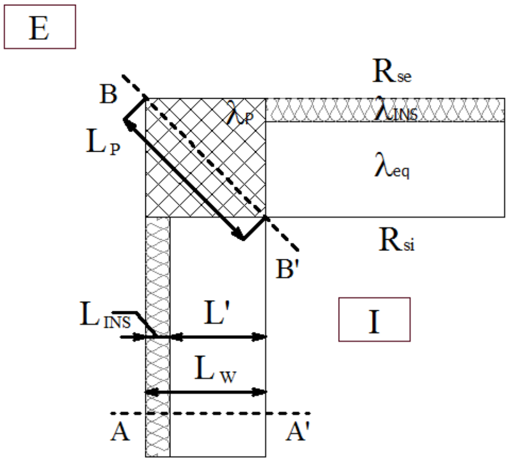
In the evaluation of the mean square error for the linear thermal transmittance in this case the V8.PIL.001 has been excluded because one of the parameters was outside of the validity field and the ΔΨ is very different from the other one and so it hasn't been possible to extrapolate the correlation.

Refering to the reports based on five validation cases, it is possible to see that with five simulation the error is greater only of the 2% and so use a smaller number of simulations is more conservative and it doesn't change a lot the final results.

For the second case the reports are the following ones:

Reference abacus case

Code	PROJECTING CORNER INSULATED OUTSIDE WITH UNINSULATED PILLAR
PC.001	



$$\psi_I = -0.018 + 0.036 \cdot U^* + 0.996 \cdot \lambda_{eq} \quad \left(\frac{W}{m \cdot K}\right)$$

$$f_{Rsi} = 0.632 - 0.246 \cdot U_W + 0.128 \cdot \lambda_{eq} (-)$$

Reference correlation accuracy

$$IC_I^{95\%} = \pm 0.11 \quad \left(\frac{W}{m \cdot K}\right)$$

$$IC_{fRsi}^{95\%} = \pm 0.01 \quad (-)$$

Evaluation of the root mean square error through real examples

	Ψ_{val}	Ψ_{ref}	$\Delta\Psi$	$\Delta\Psi^2$	MSE_Ψ	$MSEP_\Psi$
	(W/mK)	(W/mK)	(W/mK)	$(W/mK)^2$	(W/mK)	(%)
V1.PC.001	0,458	0,463	0,00	0,00	±0,03	6
V2.PC.001	0,490	0,498	-0,01	0,00		
V3.PC.001	0,509	0,527	-0,02	0,00		
V4.PC.001	0,538	0,587	-0,05	0,00		
V5.PC.001	0,414	0,421	-0,01	0,00		
V6.PC.001	0,441	0,453	-0,01	0,00		
V7.PC.001	0,470	0,460	0,01	0,00		
V8.PC.001	0,436	0,493	-0,06	0,00		
V9.PC.001	0,641	0,463	0,18	0,03		

	$f_{Rsi,val}$	$f_{Rsi,ref}$	Δf_{Rsi}	Δf^2_{Rsi}	MSE_{fRsi}	$MSEP_{fRsi}$
	(-)	(-)	(-)	(-)	(-)	(%)
V1.PC.001	0,628	0,569	0,06	0,00	+0,05	9
V2.PC.001	0,632	0,586	0,05	0,00		
V3.PC.001	0,640	0,600	0,04	0,00		
V4.PC.001	0,644	0,614	0,03	0,00		
V5.PC.001	0,640	0,577	0,06	0,00		
V6.PC.001	0,644	0,589	0,05	0,00		
V7.PC.001	0,636	0,576	0,06	0,00		
V8.PC.001	0,636	0,593	0,04	0,00		
V9.PC.001	0,564	0,569	0,00	0,00		

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
V1.PC.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,06
		U_W	(W/m^{2}K)	0,41				
	U_{av}		(W/m^{2}K)	0,65	$T_{si,min}$		(°C)	10,70
V2.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (30x30cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	2,06
		U_W	(W/m^{2}K)	0,35				
	U_{av}		(W/m^{2}K)	0,59	$T_{si,min}$		(°C)	10,80
V3.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,007	1,4	0,01
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^{2}K)	1,96
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,29				
	U_{av}		(W/m^{2}K)	0,55	$T_{si,min}$		(°C)	11,00
V4.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,007	1,4	0,01
	Polyurethan insulation	**0,09**	**0,028**	**3,21**		U_P	(W/m^{2}K)	1,96
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^{2}K)	0,23				
	U_{av}		(W/m^{2}K)	0,50	$T_{si,min}$		(°C)	11,10
V5.PC.001	WALL	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^{2}K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,3**	**0,23**	**1,30**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^{2}K)	1,92
		U_W	(W/m^{2}K)	0,35				
	U_{av}		(W/m^{2}K)	0,56	$T_{si,min}$		(°C)	11,00

Validation cases

	WALL	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	PILLAR (35x35cm)	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
V6.PC.001	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,3**	**0,23**	**1,30**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	Polyurethan insulation	**0,05**	**0,028**	**1,79**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**1,92**
		U_W	(W/m^2K)	**0,30**				
	U_{av}		(W/m^2K)	**0,52**	$T_{si,min}$		(°C)	**11,10**
V7.PC.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (35x35cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,3**	**0,288**	**1,04**	Armed concrete	**0,495**	**1,91**	**0,26**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**1,92**
		U_W	(W/m^2K)	**0,39**				
	U_{av}		(W/m^2K)	**0,62**	$T_{si,min}$		(°C)	**10,90**
V8.PC.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (30x30cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Lightened bricks	**0,2**	**0,23**	**0,87**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	External plaster	0,007	1,4	0,01
	EPS insulation	**0,09**	**0,038**	**2,37**		U_P	(W/m^2K)	**2,11**
	External plaster	0,005	1,4	0,00				
		U_W	(W/m^2K)	**0,29**				
	U_{av}		(W/m^2K)	**0,51**	$T_{si,min}$		(°C)	**10,90**
V9.PC.001	**WALL**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)	**PILLAR (40x30cm)**	L_i (m)	λ_i (W/mK)	R_i (m^2K/W)
	Chalk plaster	0,015	0,35	0,04	Chalk plaster	0,021	0,35	0,06
	Brick (25x30cm)	**0,25**	**0,288**	**0,87**	Armed concrete	**0,424**	**1,91**	**0,22**
	Concrete plaster	0,01	1,4	0,01	Alluminium vapour barrie	0,003	0,17	0,02
	Alluminium vapour barrie	0,002	0,17	0,01	Concrete plaster	0,014	1,4	0,01
	EPS insulation	**0,05**	**0,038**	**1,32**	External plaster	0,007	1,4	0,01
	External plaster	0,005	1,4	0,00		U_P	(W/m^2K)	**2,06**
		U_W	(W/m^2K)	**0,41**				
	U_{av}		(W/m^2K)	**0,74**	$T_{si,min}$		(°C)	**9,10**

Also in this case one simulation has been excluded owing to the geometry into consideration: V9.PC.001 considers a rectangular pillar whereas of a quadratic one and so the $\Delta\Psi$ and the Δf_{Rsi} are different from the other one. Comparing the values of percentage of the mean square error of nine validation cases and of five ones, it is possible to see that there isn't any difference.

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