INTERNATIONAL STANDARD

ISO 10211-2

First edition
2001-03-01

Thermal bridges in building construction — Calculation of heat flows and surface temperatures —

Part 2:
Linear thermal bridges

Ponts thermique dans les bâtiments — Calcul des flux thermiques et des températures superficielles —

Partie 2: Ponts thermiques linéaires

Reference number
ISO 10211-2:2001(E)

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Printed in Switzerland

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 10211 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10211-2 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 163, *Thermal insulation*, Subcommittee SC 2, *Calculation methods*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

ISO 10211 consists of the following parts, under the general title *Thermal bridges in building construction — Calculation of heat flows and surface temperatures*:

— *Part 1: General calculation methods*

— *Part 2: Linear thermal bridges*

Annexes A and B of this part of ISO 10211 are for information only.

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Foreword

The text of EN ISO 10211-2:2001 has been prepared by Technical Committee CEN/TC 89 "Thermal performance of buildings and building components", the secretariat of which is held by SIS, in collaboration with Technical Committee ISO/TC 163 "Thermal insulation", subcommittee 2 "Calculation methods".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2001, and conflicting national standards shall be withdrawn at the latest by December 2001.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

This standard consists of two parts. The title of part 1 is "Thermal bridges in building construction - Calculation of heat flows and surface temperatures - Part 1: General methods".

This standard is one of a series of standards on calculation methods for the design and evaluation of the thermal performance of buildings and building components.

Introduction

Part 1 of this standard gives general methods for the calculation of heat flows and surface temperatures of thermal bridges of arbitrary shape and with an arbitrary number of boundary conditions. This part deals with linear thermal bridges bounded by two different thermal environments. For the calculation of surface temperatures, a third boundary temperature applies only if the thermal bridge is in thermal contact with the ground.

A linear thermal bridge can be represented by its cross-section, which provides the basis for a two-dimensional geometrical model.

As the two-dimensional model is a simplification of the real construction, the calculation results are approximations of the results calculated with a three-dimensional model according to EN ISO 10211-1:1995. The errors due to this simplification are related to the length of the linear thermal bridge which is often not specified. The calculation methods given in part 2 are termed "Class B" methods in order to distinguish them from the "Class A" methods given in part 1.

Although similar calculation procedures are used, the procedures are not identical for the calculation of heat flows and of surface temperatures.

Part 2 of this standard lays down criteria which have to be satisfied in order that a calculation method for linear thermal bridges can be described as being "Class B".

Part 2 can be used for the calculation of the linear thermal transmittance of the linear thermal bridge.

Part 2 does not provide reliable results for the assessment of surface condensation. Although accurate internal surface temperatures can be calculated with a two dimensional model, the actual minimum surface temperature can be lower,as a result of other linear or point thermal bridges in the vicinity.

At the intersection of two or three linear thermal bridges a drop of the internal surface temperature occurs. A method to calculate the lower limiting value of the temperature factor at the intersection is given in annex B.

1 Scope

This part 2 of the standard gives the specifications for a two-dimensional geometrical model of a linear thermal bridge for the numerical calculation of:

- the linear thermal transmittance of the linear thermal bridge;
- the lower limit of the minimum surface temperatures.

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

The standard is based upon the following assumptions:

- steady-state conditions apply;
- all physical properties are independent of temperature;
- there are no heat sources within the building element;
- only one internal thermal environment applies;
- one or two external thermal environments apply.

A second external thermal environment only applies when surface temperatures are calculated and the soil is a part of the geometrical model. In that case the temperature at the horizontal cut-off plane in the soil is the second external thermal environment.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 7345	Thermal insulation - Physical quantities and definitions (ISO7345:1987)
EN ISO 10211-1:1995	Thermal bridges in building construction - Heat flows and surface temperatures - Part 1: General calculation methods (ISO 10211-1:1995)

3 Terms, definitions, symbols and units

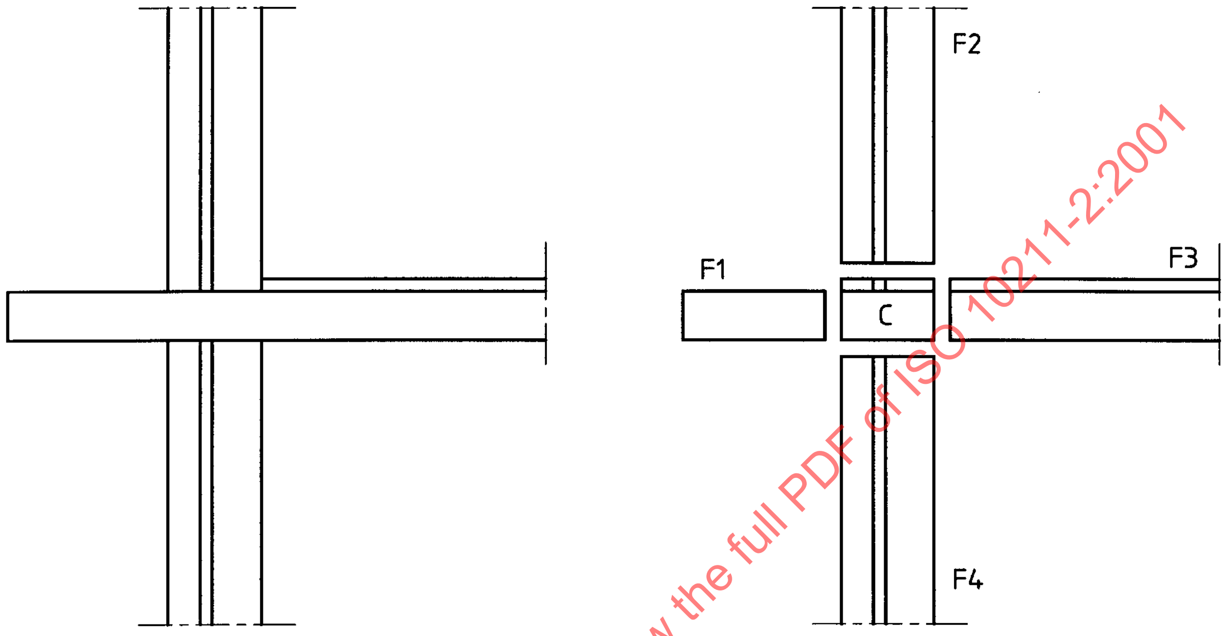
3.1 Terms and definitions

For the purposes of this standard the terms and definitions given in EN ISO 7345, EN ISO 10211-1:1995 and the following apply.

3.1.1
linear thermal bridge
thermal bridge with a uniform cross-section along one of the three orthogonal axes

3.1.2
2-D flanking element
part of a two-dimensional (2-D) geometrical model which, when considered in isolation, consists of plane, parallel material layers

3.1.3
2-D central element
part of a 2-D geometrical model which is not a 2-D flanking element



F1 to F4 have constant cross-sections. C is the remaining part.

Figure 1 - 2-D model with four flanking elements and a central element

3.2 Symbols and units

Symbol	Physical quantity	Unit
L^{2D}	linear thermal coupling coefficient	W/(m·K)
R_t	surface to surface thermal resistance	m²·K/W
R_{se}	external surface resistance	m²·K/W
R_{si}	internal surface resistance	m²·K/W
U	thermal transmittance	W/(m²·K)
b	ground floor width	m
f_{Rsi}^{3D}	temperature factor at the intersection of linear thermal bridges	-
f_{Rsi}^{2D}	temperature factor of a linear thermal bridge	-
f_{Rsi}^{1D}	temperature factor of a plane building element with uniform thermal resistance	-
g	temperature weighting factor	-
l	length	m
q	density of heat flow rate	W/m²
θ	Celsius temperature	°C
λ	thermal conductivity	W/(m·K)
ζ_{Rsi}	temperature difference ratio	-
Φ	heat flow rate	W
Ψ	linear thermal transmittance	W/(m·K)

Subscripts

e external
i internal
s surface
l length

Superscripts

1D refers to a one-dimensional geometrical model
2D refers to a two-dimensional geometrical model
3D refers to a three-dimensional geometrical model

4 Rules for modelling

4.1 Cut-off planes of the geometrical model

The geometrical model includes the 2-D central element, the 2-D flanking elements and, where appropriate, the subsoil. The geometrical model is delimited by cut-off planes.

Cut-off planes shall be positioned as follows:
- at least 1 m from the central element if there is no nearer symmetry plane (see Figure 2);
- at a symmetry plane if this is less than 1 m from the central element (see Figure 3);
- in the ground according to Table 1 (see Figure 4).

Dimensions in millimetres

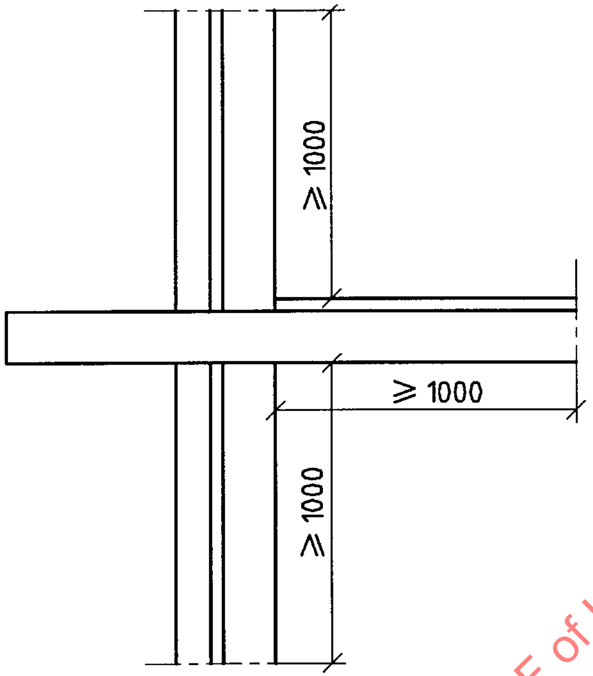


Figure 2 - Location of cut-off planes at least 1 m from the central element

Dimensions in millimetres

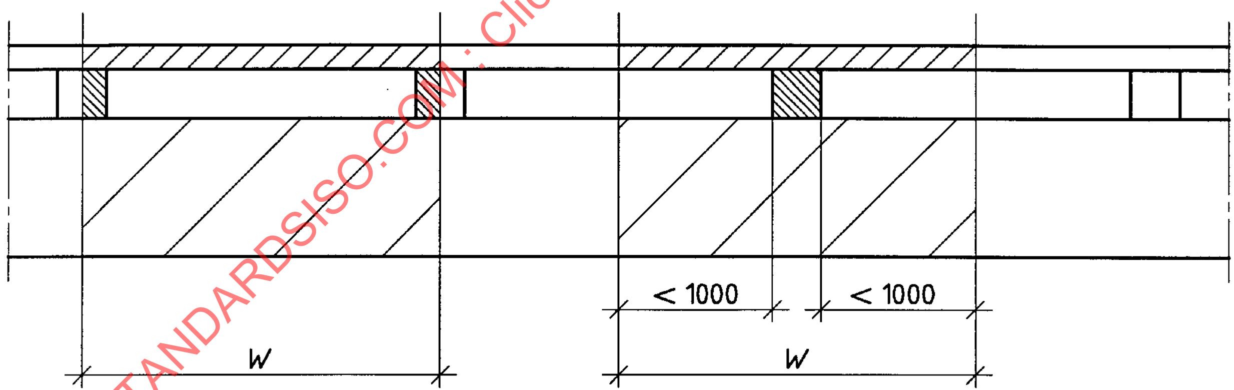


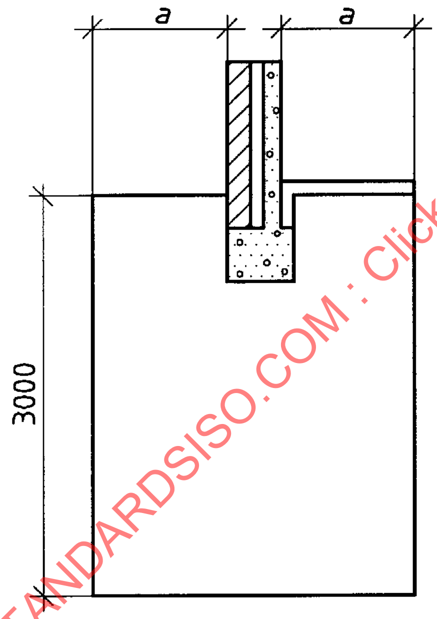
Figure 3 - Example of a construction with linear thermal bridges at fixed distances *W*, showing symmetry planes which can be used as cut-off planes

Table 1 - Location of cut-off planes in the subsoil
(foundations, ground floors, basements)

Direction	Distance to central element	
	Surface temperature calculations, see Figure 4a)	Heat flow calculations, see Figure 4b)
Horizontal inside the building	at least 1 m	0,5 *b* [1)]
Horizontal outside the building	same distance as inside the building	2,5 *b* [1)]
Vertical below ground level	3 m	2,5 *b* [1)]
Vertical below floor level [2)]	1 m	-

1) If the value of *b* is not given the default value *b* = 8 m shall be applied.
2) This value applies only if the level of the floor under consideration is more than 2 m below the ground surface.

Dimensions in millimetres



$a \geqslant 1000$

Figure 4a) - Soil dimensions for calculation of surface temperatures

Dimensions in metres

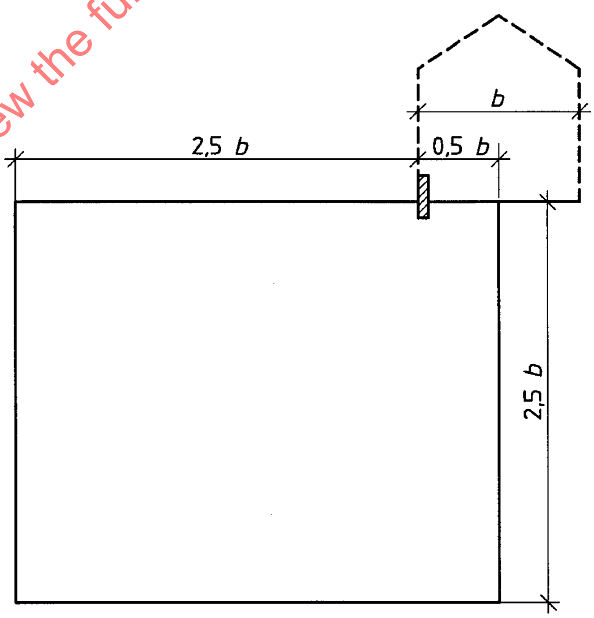


Figure 4b) - Soil dimensions for calculation of heat flow

4.2 Adjustments to dimensions

Adjustments to the dimensions of the geometrical model with respect to the geometry as specified in the architectural drawing are only allowed if they have no significant influence on the result of the calculation; this can be assumed if the conditions of 5.2.1 of EN ISO 10211-1:1995 are satisfied.

Point thermal bridges that may be part of the architectural drawing (e.g. screws) should be ignored. The thermal effect of distributed point thermal bridges should be incorporated into the thermal conductivity of the material layers according to clause 5 of EN ISO 10211-1:1995.

4.3 Auxiliary planes

Planes which are necessary to separate blocks of different materials are called construction planes. Planes which are neither construction planes nor cut-off planes are called auxiliary planes.

The number of auxiliary planes in the model shall be such that doubling the number of subdivisions does not change the linear coupling coefficient by more than 2 %, otherwise further subdivisions shall be made until this criterion is met.

Dimensions in millimetres

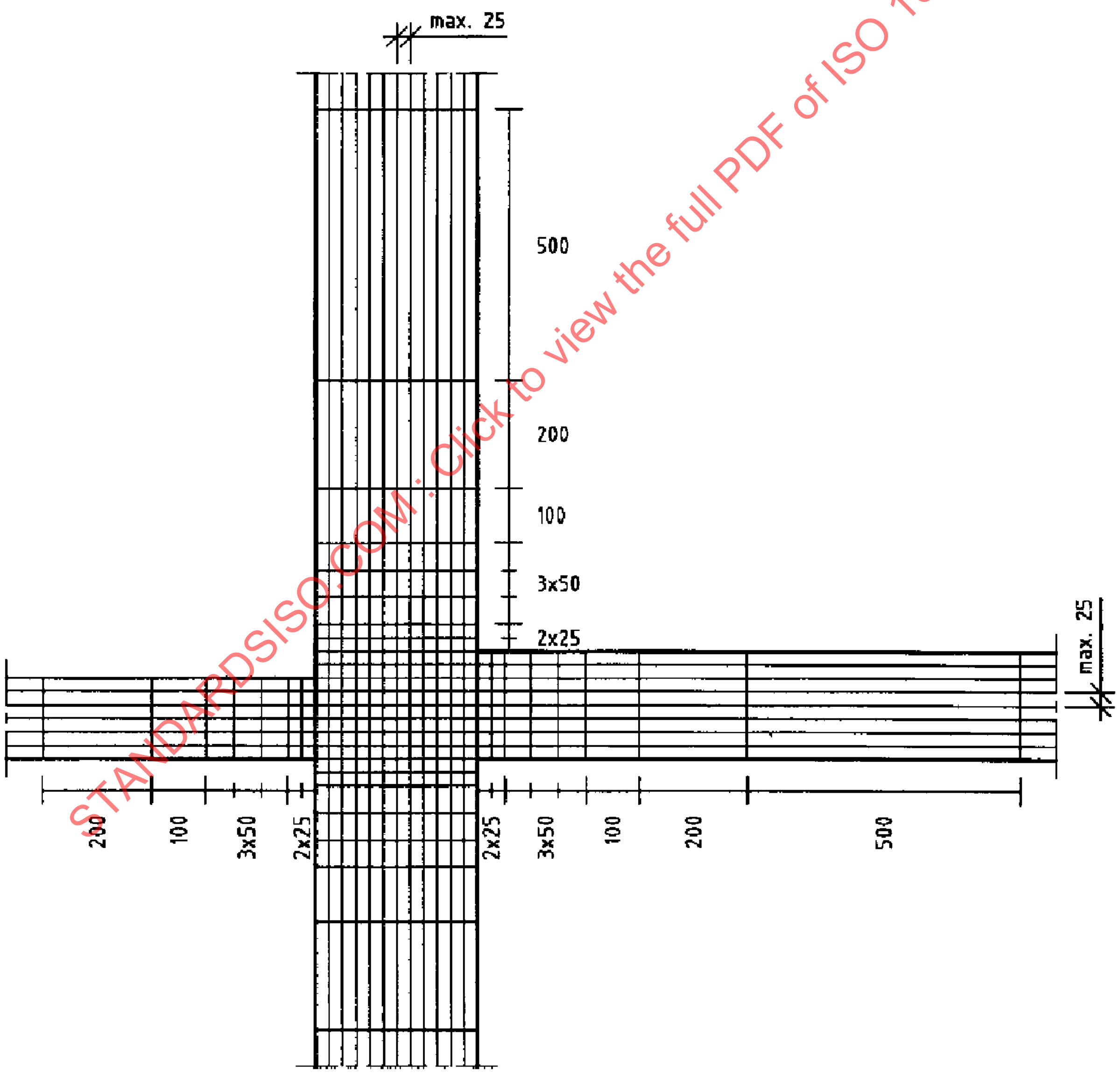


Figure 5 - Example of construction planes supplemented with auxiliary planes

NOTE this requirement is in many cases fulfilled when the distance between adjacent parallel planes does not exceed the following values
(see Figure 5):
- within the central element 25 mm;
- within the flanking elements, measured from the construction plane which separates the central element from the flanking element: 25, 25, 50, 50, 50, 100, 200, 500, 1000, 2000 and 4000 mm.

For constructions with indentations of small dimensions (e.g. window profiles) a finer subdivision is needed.

5 Calculation values

Clause 6 of EN ISO 10211-1:1995 applies. 6.2.1 and 6.2.3 of EN ISO 10211-1:1995 are optional. For the determination of the thermal conductivity of air voids and cavities 6.2.2 of EN ISO 10211-1:1995 shall be used.

NOTE A separate standard[1)] is under preparation which gives values for irregular shapes.

6 Calculation method

6.1 Calculation programs

Calculation programs shall be validated according to annex A of EN ISO 10211-1:1995.

6.2 Calculation rules

The cut-off planes shall be adiabatic (i.e. zero heat flow) with the exception of the horizontal cut-off plane in the soil in the case of calculation of the surface temperature. The temperature of this cut-off plane is to be taken as the value of the yearly average external air temperature.

6.3 Determination of the thermal coupling coefficient, the heat flow rate, and the linear thermal transmittance

6.3.1 *Boundary conditions*

Only two boundary temperatures apply, the external temperature and the internal temperature.

6.3.2 *Determination of the thermal coupling coefficient and the heat flow rate*

The heat flow rate per metre length, Φ_l, of the linear thermal bridge from the internal environment i to the external environment e is given by:

$$\Phi_l = L^{2D}(\theta_i - \theta_e) \quad (1)$$

where:

L^{2D} is the linear thermal coupling coefficient obtained from a 2-D calculation of the component separating the two environments being considered.

1) prEN ISO 10077-2 "Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames (ISO/DIS 10077-2:1998)" is in preparation.

6.3.3 *Determination of the linear thermal transmittance*

The linear thermal transmittance is given by:

$$\Psi = L^{2D} - \sum_{j=1}^{N} U_j \, l_j \qquad (2)$$

where:

Ψ is the linear thermal transmittance of the linear thermal bridge separating the two environments being considered;
U_j is the thermal transmittance of the 1-D component j separating the two environments being considered;
l_j is the length within the 2-D geometrical model over which the value U_j applies;
N is the number of 1-D components.

When determining the linear thermal transmittance, it is necessary to state which dimensions (e.g. internal or external) are being used because for several types of thermal bridges the value of the linear thermal transmittance depends on this choice.

6.4 Determination of the temperature at the internal surface

6.4.1 *General*

Normally two boundary temperatures apply. A third boundary temperature shall be used as specified in 6.2 only in the case where the subsoil is a part of the geometrical model.

6.4.2 *Two boundary temperatures*

When there are only two environments involved, the surface temperatures can be expressed in a dimensionless form according to equation (3) or equation (4):

$$\zeta_{Rsi}(x,y) = \frac{\theta_i - \theta_{si}(x,y)}{(\theta_i - \theta_e)} \qquad (3)$$

or:

$$f_{Rsi}(x,y) = \frac{\theta_{si}(x,y) - \theta_e}{(\theta_i - \theta_e)} \qquad (4)$$

where:

$\zeta_{Rsi}(x,y)$ is the temperature difference ratio for the internal surface at point (x,y);
$f_{Rsi}(x,y)$ is the temperature factor for the internal surface at point (x,y);
$\theta_{si}(x,y)$ is the temperature for the internal surface at point (x,y);
θ_i is the internal air temperature;
θ_e is the external air temperature.

The temperature difference ratio or the temperature factor shall be calculated with an error of less than 0,005.

6.4.3 *Three boundary temperatures*

If there are three boundary temperatures involved, temperature weighting factors g shall be used. Temperature weighting factors provide the means to calculate the temperature at any location of the internal surface with coordinates (x,y) as a linear function of any set of boundary temperatures.

The temperature weighting factors at the location (x,y) are given by:

$$\theta_{si}(x,y) = g_1(x,y)\ \theta_1 + g_2(x,y)\ \theta_2 + g_3(x,y)\ \theta_3 \tag{5}$$

with:

$$g_1(x,y) + g_2(x,y) + g_3(x,y) = 1 \tag{6}$$

NOTE The weighting factors at the location of interest can be calculated according to annex A. Normally the location of interest is the point with the lowest internal surface temperature. This location can vary if the boundary temperatures are changed.

Calculate the internal surface temperature θ_{si} at the location of interest by inserting the calculated values of g_1, g_2 and g_3 and the actual boundary temperatures θ_1, θ_2 and θ_3 in equation (5).

7 Input and output data

7.1 Input data

The report of the calculation shall contain the following information:

a) **Description of structure:**
- building plans including dimensions, materials and thermally relevant information;
- for a completed building, any known alterations to the construction and/or physical measurements and details from inspection;

b) **Description of the geometrical model:**
- 2-D model with dimensions;
- input data which show the location of the construction planes and any auxiliary planes together with the thermal conductivities of the various materials;
- the applied boundary temperatures;
- the surface resistances and the areas to which they apply;
- any non-standard values used with justification of the deviation from standard values.

7.2 Output data

7.2.1 *General*

The following calculation results shall be reported as values which are independent of the boundary temperatures:

- thermal coupling coefficient L between the internal and external environments;
- the linear thermal transmittance, Ψ, of the linear thermal bridge;
- temperature factors f_{Rsi} or temperature difference ratios ζ_{Rsi} for the points of lowest surface temperatures in each room involved (including the location of these points); if three boundary temperatures are used, the temperature weighting factors shall be reported.

NOTE An example showing how to report temperature weighting factors is given in Table A.1.

All output values shall be given to at least three significant figures.

7.2.2 *Calculation of the heat flow rate using the thermal coupling coefficient*

The heat flow rate from the internal to the external environment is given by equation (1).

7.2.3 *Calculating surface temperatures using weighting factors*

The lowest internal surface temperature in each of the rooms that are part of the internal environment is the minimum temperature calculated using equation (5).

7.2.4 *Additional output data*

For a specific set of boundary temperatures the following additional values shall be presented:

- heat flows (in watts per metre) for each room of interest;
- minimum surface temperatures (in degrees Celsius) and the location of the points with minimum surface temperature in each room of interest.

7.2.5 *Estimate of error*

In order to estimate errors arising in the numerical solution of the equation system, the algebraic sum of heat flows over all boundaries of the building component divided by half the sum of the absolute values of these heat flows shall be given.

NOTE Annex A of EN ISO 10211-1:1995 specifies that this quotient is to be less than 0,001.

Annex A
(informative)

Determination of temperature weighting factors for three boundary temperatures

For a model with three boundary temperatures (i.e the internal and the external environment and the temperature of the horizontal cut-off plane in the ground), the weighting factors can be calculated by twice performing the calculation of the temperature at the selected point; in both calculations all the boundary temperatures are equal to zero except one boundary temperature, which equals 1 K, as shown in Table A.1:

Table A.1 - Scheme for calculating *g*-values in the case of 3 boundary temperatures

Calculation number	Values of boundary temperatures			Weighting factor
	θ_1	θ_2	θ_3	
1	1	0	0	g_1
2	0	1	0	g_2

g_3 follows from equation (6).

Report the set of R_{si} values used in the calculation of the temperature weighting factors and provide a sketch that shows to which internal surface area each R_{si} value applies.