INTERNATIONAL STANDARD

ISO 10211

First edition
2007-12-15

Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations

Ponts thermiques dans les bâtiments — Flux thermiques et températures superficielles — Calculs détaillés

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Reference number
ISO 10211:2007(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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 the member bodies casting a vote.

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

ISO 10211 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*.

This first edition of ISO 10211 cancels and replaces ISO 10211-1:1995 and ISO 10211-2:2001, which have been technically revised.

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The principal changes are as follows:

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- this first edition of ISO 10211 merges the title and general contents of ISO 10211-1:1995 and ISO 10211-2:2001 into a single document;
- Clause 3 indicates that ISO 10211 now uses only temperature factor, and not temperature difference ratio;
- 5.2.2 specifies that cut-off planes are to be located at the larger of 1 m and three times the thickness of the flanking element;
- 5.2.4 contains a revised version of Table 1 to correct error for three-dimensional calculations and to clarify intentions;
- 5.2.7 specifies that acceptable criterion is either on heat flow or on surface temperature; the heat flow criterion has been changed from 2 % to 1 %;
- 6.3 specifies that surface resistance values are to be obtained from ISO 6946 for heat flow calculations and from ISO 13788 for condensation calculations; the contents of Annexes E and G of ISO 10211-1:1995 have been deleted in favour of references to ISO 13788;
- 6.6 specifies that data for air cavities is obtained from ISO 6946, EN 673 or ISO 10077-2; the contents of Annex B of ISO 10211-1:1995 have been deleted in favour of these references;
- 10.4 contains text formerly in ISO 13370, revised to specify that linear thermal transmittance values for wall/floor junctions are the difference between the numerical result and the result from using ISO 13370 (a more consistent definition);
- Annex A contains corrections to results for case 3; the conformity criterion for case 3 has been changed from 2 % of heat flow to 1 %; a new case 4 has been added;
- Annex C contains a corrected procedure;
- all remaining annexes from ISO 10211-1:1995 and ISO 10211-2:2001 have been deleted.

Introduction

Thermal bridges, which in general occur at any junction between building components or where the building structure changes composition, have two consequences compared with those of the unbridged structure:

a) a change in heat flow rate, and

b) a change in internal surface temperature.

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.

A discussion of other methods for assessing the effect of thermal bridges is provided in ISO 14683.

ISO 10211 was originally published in two parts, dealing with three-dimensional and two-dimensional calculations separately.

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Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations

1 Scope

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.

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

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

ISO 7345, *Thermal insulation — Physical quantities and definitions*

ISO 13370:2007, *Thermal performance of buildings — Heat transfer via the ground — Calculation methods*

ISO 13788, *Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods*

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3 Terms, definitions, symbols, units and subscripts

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345 and the following apply.

3.1.1
thermal bridge
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

3.1.2
linear thermal bridge
thermal bridge with a uniform cross-section along one of the three orthogonal axes

3.1.3
point thermal bridge
localized thermal bridge whose influence can be represented by a point thermal transmittance

3.1.4
three-dimensional geometrical model
3-D geometrical model
geometrical model, deduced from building plans, such that for each of the orthogonal axes the cross-section perpendicular to that axis changes within the boundary of the model

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See Figure 1.

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3.1.5
three-dimensional flanking element
3-D flanking element
part of a 3-D geometrical model which, when considered in isolation, can be represented by a 2-D geometrical model

See Figures 1 and 2.

3.1.6
three-dimensional central element
3-D central element
part of a 3-D geometrical model which is not a 3-D flanking element

See Figure 1.

NOTE A central element is represented by a 3-D geometrical model.

3.1.7
two-dimensional geometrical model
2-D geometrical model
geometrical model, deduced from building plans, such that for one of the orthogonal axes the cross-section perpendicular to that axis does not change within the boundaries of the model

See Figure 2.

NOTE A 2-D geometrical model is used for two-dimensional calculations.

3.1.8
two-dimensional flanking element
2-D flanking element
part of a 2-D geometrical model which, when considered in isolation, consists of plane, parallel material layers

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3.1.9
two-dimensional central element
2-D central element
part of a 2-D geometrical model which is not a 2-D flanking element

3.1.10
construction planes
planes in the 3-D or 2-D geometrical model which separate different materials, and/or the geometrical model from the remainder of the construction, and/or the flanking elements from the central element

See Figure 3.

3.1.11
cut-off planes
construction planes that are boundaries to the 3-D or 2-D geometrical model by separating the model from the remainder of the construction

See Figure 3.

3.1.12
auxiliary planes
planes which, in addition to the construction planes, divide the geometrical model into a number of cells

3.1.13
quasi-homogeneous layer
layer which consists of two or more materials with different thermal conductivities, but which can be considered as a homogeneous layer with an effective thermal conductivity

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See Figure 4.

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3.1.14
temperature factor at the internal surface
difference between internal surface temperature and external temperature, divided by the difference between internal temperature and external temperature, calculated with a surface resistance R_{si} at the internal surface

3.1.15
temperature weighting factor
weighting factor which states the respective influence of the temperatures of the different thermal environments upon the surface temperature at the point under consideration

3.1.16
external boundary temperature
external air temperature, assuming that the air temperature and the radiant temperature seen by the surface are equal

3.1.17
internal boundary temperature
operative temperature, taken for the purposes of this International Standard as the arithmetic mean value of internal air temperature and mean radiant temperature of all surfaces surrounding the internal environment

3.1.18
thermal coupling coefficient
heat flow rate per temperature difference between two environments which are thermally connected by the construction under consideration

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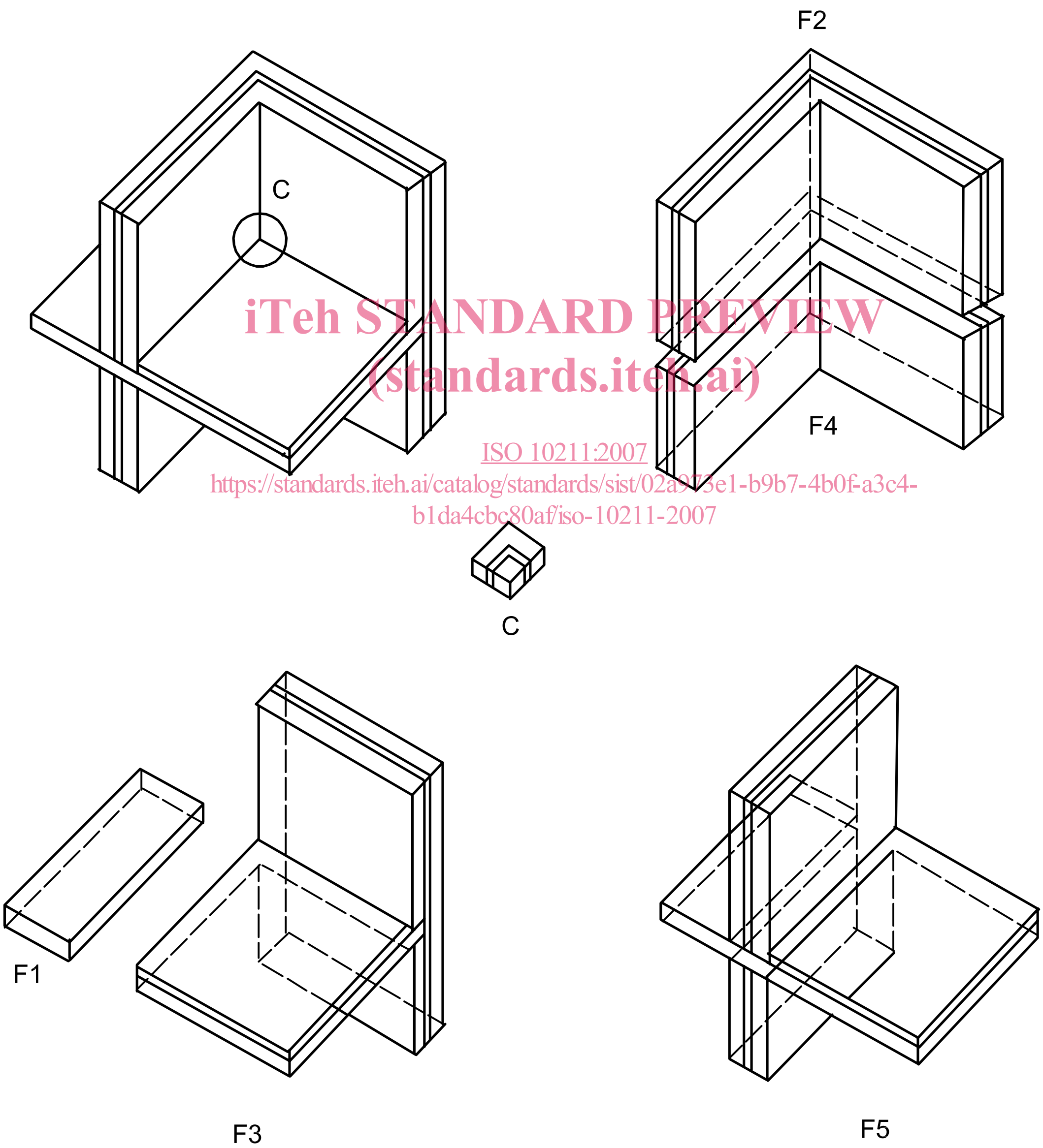
3.1.19
linear thermal transmittance
heat flow rate in the steady state divided by length and by the temperature difference between the environments on either side of a thermal bridge

NOTE The linear thermal transmittance is a quantity describing the influence of a linear thermal bridge on the total heat flow.

3.1.20
point thermal transmittance
heat flow rate in the steady state divided by the temperature difference between the environments on either side of a thermal bridge

NOTE The point thermal transmittance is a quantity describing the influence of a point thermal bridge on the total heat flow.



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Key

F1, F2, F3, F4, F5 3-D flanking elements

C 3-D central element

NOTE 3-D Flanking elements have constant cross-sections perpendicular to at least one axis; the 3-D central element is the remaining part.

Figure 1 — 3-D geometrical model with five 3-D flanking elements and one 3-D central element

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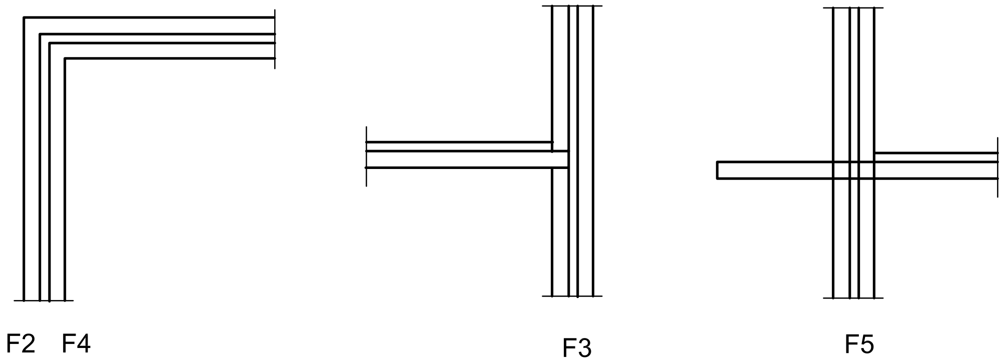


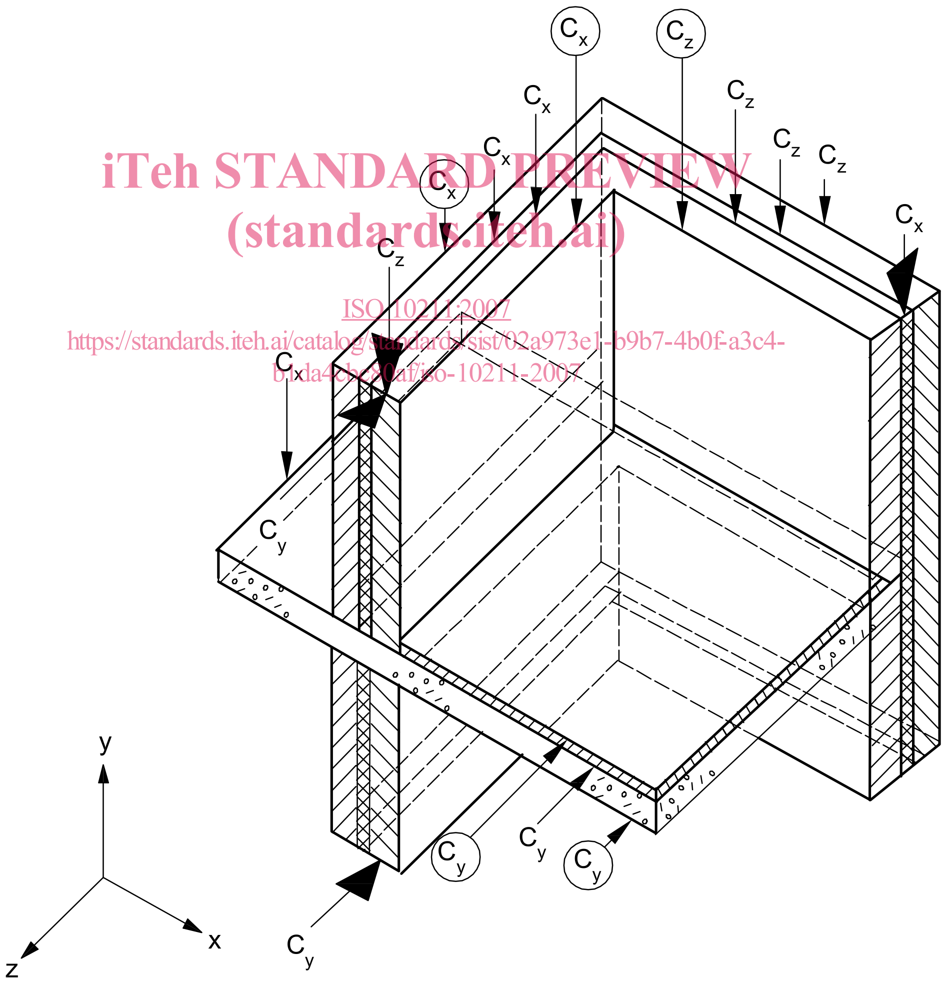
Key

F2, F3, F4, F5 3-D flanking elements

C 3-D central element

NOTE F2 to F5 refer to Figure 1.

Figure 2 — Cross-sections of the 3-D flanking elements in a 3-D geometrical model treated as 2-D geometrical models



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Key

C_x construction planes perpendicular to the x-axis

C_y construction planes perpendicular to the y-axis

C_z construction planes perpendicular to the z-axis

NOTE Cut-off planes are indicated with enlarged arrows; planes that separate flanking elements from central element are encircled.

Figure 3 — Example of a 3-D geometrical model showing construction planes

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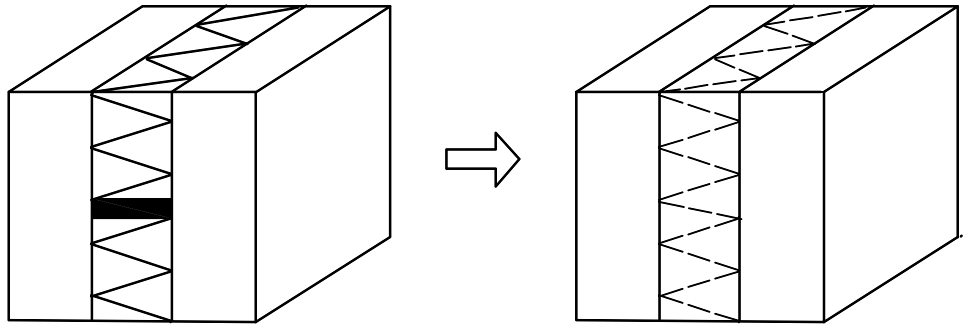

Figure 4 — Example of a minor point thermal bridge giving rise to three-dimensional heat flow, incorporated into a quasi-homogeneous layer

3.2 Symbols and units

Symbol	Quantity	Unit
A	area	m^2
B'	characteristic dimension of floor	m
b	width	m
d	thickness	m
f_{Rsi}	temperature factor at the internal surface	–
g	temperature weighting factor	–
h	height	m
L_{2D}	thermal coupling coefficient from two-dimensional calculation	W/(m·K)
L_{3D}	thermal coupling coefficient from three-dimensional calculation	W/K
l	length	m
q	density of heat flow rate	W/m^2
R	thermal resistance	$m^2·K/W$
R_{se}	external surface resistance	$m^2·K/W$
R_{si}	internal surface resistance	$m^2·K/W$
T	thermodynamic temperature	K
U	thermal transmittance	$W/(m^2·K)$
V	volume	m^3
w	wall thickness	m
Φ	heat flow rate	W
λ	thermal conductivity	W/(m·K)
θ	Celsius temperature	°C
$\Delta\theta$	temperature difference	K
χ	point thermal transmittance	W/K
Ψ	linear thermal transmittance	W/(m·K)

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3.3 Subscripts

Subscript	Definition
e	external
i	internal
min	minimum
s	surface

4 Principles

The temperature distribution within, and the heat flow through, a construction can be calculated if the boundary conditions and constructional details are known. For this purpose, the geometrical model is divided into a number of adjacent material cells, each with a homogeneous thermal conductivity. The criteria which shall be met when constructing the model are given in Clause 5.

In Clause 6, instructions are given for the determination of the values of thermal conductivity and boundary conditions.

The temperature distribution is determined either by means of an iterative calculation or by a direct solution technique, after which the temperature distribution within the material cells is determined by interpolation. The calculation rules and the method of determining the temperature distribution are described in Clause 7.

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The results of the calculations can be used to determine linear thermal transmittances, point thermal transmittances and internal surface temperatures. The equations for doing so are provided in Clauses 9, 10 and 11.

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Specific procedures for window frames are given in ISO 10077-2.

5 Modelling of the construction

5.1 Dimension systems

Lengths may be measured using internal dimensions, overall internal dimensions or external dimensions, provided that the same system is used consistently for all parts of a building.

NOTE For further information on dimension systems, see ISO 13789.

5.2 Rules for modelling

5.2.1 General

It is not usually feasible to model a complete building using a single geometrical model. In most cases, the building may be partitioned into several parts (including the subsoil, where appropriate) by using cut-off planes. This partitioning shall be performed in such a way that all differences are avoided in the results of calculation between the partitioned building and the building when treated as a whole. This partitioning into several geometrical models is achieved by choosing suitable cut-off planes.

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5.2.2 Cut-off planes for a 3-D geometrical model for calculation of total heat flow and/or surface temperatures

The geometrical model includes the central element(s), the 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 a symmetry plane if this is less than d_{min} from the central element (see Figure 5);

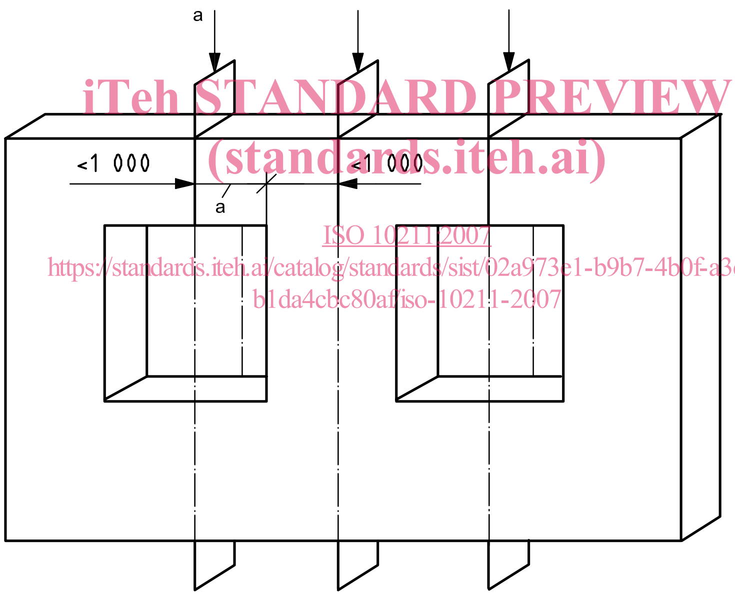
— at least d_{min} from the central element if there is no nearer symmetry plane (see Figure 6);

— in the ground, in accordance with 5.2.4,

where d_{min} is the greater of 1 m and three times the thickness of the flanking element concerned.

A geometrical model can contain more than one thermal bridge. In such cases, cut-off planes need to be situated at least d_{min} from each thermal bridge, or need to be at a symmetry plane (see Figure 6).

Dimensions in millimetres



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a Arrows indicate the symmetry planes.

Figure 5 — Symmetry planes which can be used as cut-off planes

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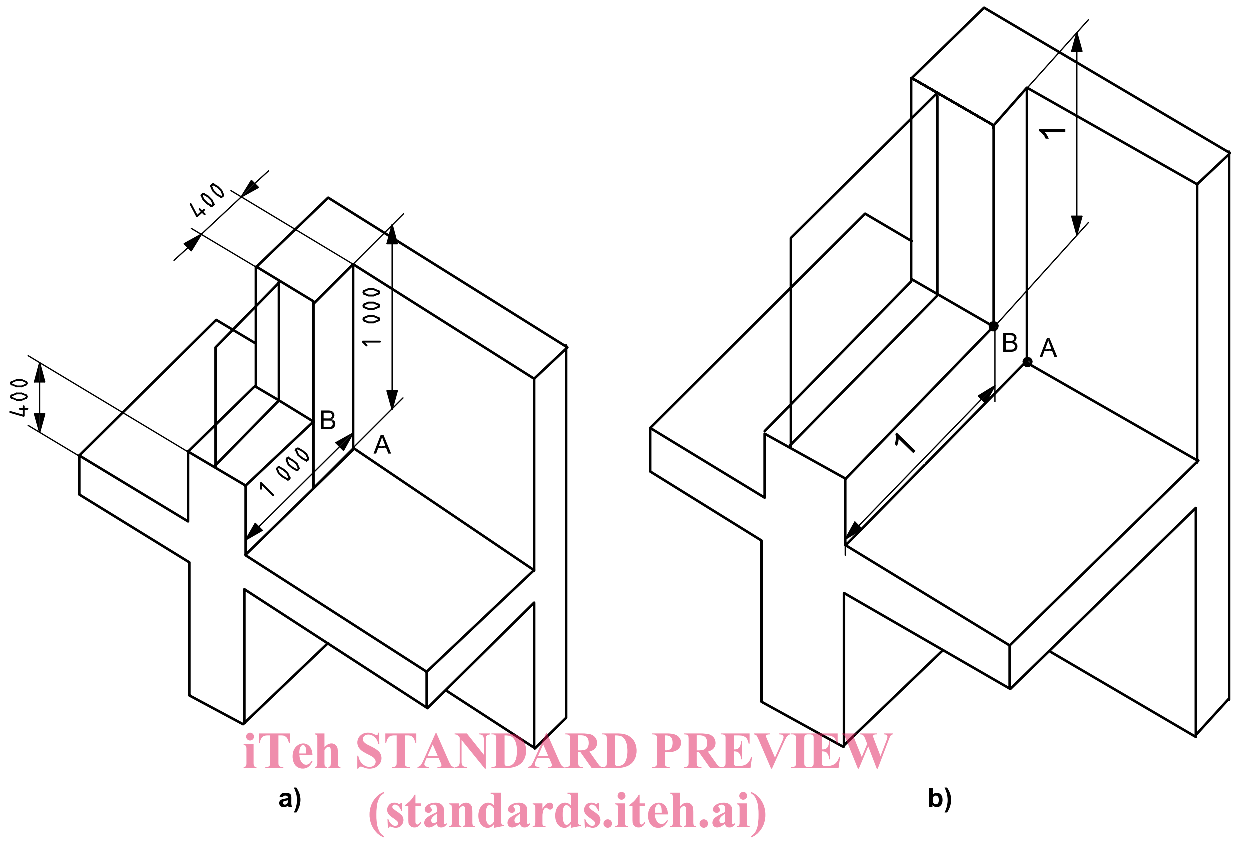
Dimensions in millimetres



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Key

1 1 000 mm or at a symmetry plane

A thermal bridge at the corner of the internal room

B thermal bridge around the window in the external wall

NOTE Thermal bridge B does not fulfil the condition of being at least d_{min} (= 1 m) from a cut-off plane [Figure 6 a)]. This is corrected by extending the model in two directions [Figure 6 b)].

Figure 6 — 3-D geometrical model containing two thermal bridges

5.2.3 Cut-off planes for a 2-D geometrical model

The same rules as given in 5.2.2 apply to a 2-D geometrical model. Examples are shown in Figures 7 and 8. In Figure 8, the left-hand drawing may be used if the thermal bridge is symmetrical.

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