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Thermal performance of buildings — Heat transfer via the ground — Calculation methods

Performance thermique des bâtiments — Transfert de chaleur par le sol — Méthodes de calcul

Reference number
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www. iso. org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www. iso. org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso. org/iso/foreword. html.

ISO 13370 was prepared by ISO Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 89, *Thermal performance of buildings and building components,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 13370:2007), which has been technically revised.

The changes in this third edition are mostly editorial. This document has been re-drafted according to CEN/TS 16629:2014. Some additional output variables have been introduced to facilitate the linkages between this document and ISO 52016-1.

Introduction

This document is part of a series aimed at the international harmonization of the methodology for assessing the energy performance of buildings. Throughout, this series is referred to as a “set of EPB standards”.

All EPB standards follow specific rules to ensure overall consistency, unambiguity and transparency.

All EPB standards provide a certain flexibility with regard to the methods, the required input data and references to other EPB standards, by the introduction of a normative template in Annex A and Annex B with informative default choices.

For the correct use of this document, a normative template is given in Annex A to specify these choices. Informative default choices are provided in Annex B.

The main target groups for this document are architects, engineers and regulators.

Use by or for regulators: In case the document is used in the context of national or regional legal requirements, mandatory choices may be given at national or regional level for such specific applications. These choices (either the informative default choices from Annex B or choices adapted to national/regional needs, but in any case following the template of Annex A) can be made available as national annex or as separate (e.g. legal) document (national data sheet).

NOTE 1 So in this case:

— the regulators will specify the choices;

— the individual user will apply the document to assess the energy performance of a building, and thereby use the choices made by the regulators.

Topics addressed in this document can be subject to public regulation. Public regulation on the same topics can override the default values in Annex B. Public regulation on the same topics can even, for certain applications, override the use of this document. Legal requirements and choices are in general not published in standards but in legal documents. In order to avoid double publications and difficult updating of double documents, a national annex may refer to the legal texts where national choices have been made by public authorities. Different national annexes or national data sheets are possible, for different applications.

It is expected, if the default values, choices and references to other EPB standards in Annex B are not followed due to national regulations, policy or traditions, that:

— national or regional authorities prepare data sheets containing the choices and national or regional values, according to the model in Annex A. In this case a national annex (e.g. NA) is recommended, containing a reference to these data sheets;

— or, by default, the national standards body will consider the possibility to add or include a national annex in agreement with the template of Annex A, in accordance to the legal documents that give national or regional values and choices.

Further target groups are parties wanting to motivate their assumptions by classifying the building energy performance for a dedicated building stock.

More information is provided in the Technical Report (ISO/TR 52019-2) accompanying this document.

The subset of EPB standards prepared under the responsibility of ISO/TC 163/SC 2 cover *inter alia*:

— calculation procedures on the overall energy use and energy performance of buildings;

— calculation procedures on the internal temperature in buildings (e.g. in case of no space heating or cooling);

— indicators for partial EPB requirements related to thermal energy balance and fabric features;

— calculation methods covering the performance and thermal, hygrothermal, solar and visual characteristics of specific parts of the building and specific building elements and components, such as opaque envelope elements, ground floor, windows and facades.

ISO/TC 163/SC 2 cooperates with other technical committees for the details on appliances, technical building systems, indoor environment, etc.

This document provides the means (in part) to assess the contribution that building products and services make to energy conservation and to the overall energy performance of buildings.

In contrast with ISO 6946, which gives the method of calculation of the thermal transmittance of building elements in contact with the external air, this document deals with elements in thermal contact with the ground. The division between these two International Standards is at the level of the inside floor surface for slab-on-ground floors, suspended floors and unheated basements, and at the level of the external ground surface for heated basements. In general, a term to allow for a thermal bridge associated with the wall/floor junction is included when assessing the total heat loss from a building using methods such as ISO 13789.

The calculation of heat transfer through the ground can be done by numerical calculations, which also allow analysis of thermal bridges, including wall/floor junctions, for assessment of minimum internal surface temperatures.

In this document, methods are provided which take account of the three-dimensional nature of the heat flow in the ground below buildings.

Thermal transmittances of floors give useful comparative values of the insulation properties of different floor constructions and are used in building regulations in some countries for the limitation of heat losses through floors.

Thermal transmittance, although defined for steady-state conditions, also relates average heat flow to average temperature difference. In the case of walls and roofs exposed to the external air, there are daily periodic variations in heat flow into and out of storage related to daily temperature variations, but this averages out, and the daily average heat loss can be found from the thermal transmittance and daily average inside-to-outside temperature difference. For floors and basement walls in contact with the ground, however, the large thermal inertia of the ground results in periodic heat flows related to the annual cycle of internal and external temperatures. The steady-state heat flow is often a good approximation to the average heat flow over the heating season.

In addition to the steady-state part, a detailed assessment of floor losses is obtained from annual periodic heat transfer coefficients related to the thermal capacity of the soil, as well as its thermal conductivity, together with the amplitude of annual variations in monthly mean temperature.

Annex F provides a method for incorporating heat transfers to and from the ground into calculations undertaken at short time intervals (e.g. 1 h).

ISO/TR 52019-2 provides information on

— thermal properties of the ground,

— the influence of flowing ground water,

— ground floors with an embedded heating or cooling system, and

— ground floors of cold stores

along with worked examples illustrating the use of the procedures in this document.

Table 1 shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

NOTE 2 In ISO/TR 52000-2, the same table can be found, with, for each module, the numbers of the relevant EPB standards and accompanying technical reports that are published or in preparation.

NOTE 3 The modules represent EPB standards, although one EPB standard could cover more than one module and one module could be covered by more than one EPB standard, for instance, a simplified and a detailed method respectively. See also Tables A.1 and B.1.

Table 1 — Position of this document (*in casu* M2–5) within the modular structure of the set of EPB standards

	Overarching		Building (as such)		Technical building systems									
Submodule	**Descriptions**		**Descriptions**		**Descriptions**	**Heating**	**Cooling**	**Ventilation**	**Humidification**	**Dehumidification**	**Domestic hot water**	**Lighting**	**Building automation and control**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
1	General		General		General									
2	Common terms and definitions; symbols, units and subscripts		Building energy needs		Needs								a	
3	Applications		(Free) Indoor conditions without systems		Maximum load and power									
4	Ways to express energy performance		Ways to express energy performance		Ways to express energy performance									
5	Building categories and building boundaries		Heat transfer by transmission	ISO 13370	Emission and control									
6	Building occupancy and operating conditions		Heat transfer by infiltration and ventilation		Distribution and control									
7	Aggregation of energy services and energy carriers		Internal heat gains		Storage and control									
8	Building zoning		Solar heat gains		Generation and control									

a The shaded modules are not applicable.

Table 1 *(continued)*

	Overarching		Building (as such)		Technical building systems									
Sub mo dule	**Descrip tions**		**Descrip tions**		**Descrip tions**	**Hea ting**	**Coo ling**	**Ven tila tion**	**Hu mi difi ca tion**	**De hu mi difi ca tion**	**Do mes tic hot wat er**	**Ligh ting**	**Buil ding auto ma tion and cont rol**	**PV, wind, ..**
sub1		**M1**		**M2**		**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**
9	Calculated energy perfor- mance		Building dynamics (thermal mass)		Load dispatch- ing and oper- ating conditions									
10	Measured energy perfor- mance		Measured energy perfor- mance		Measured energy perfor- mance									
11	Inspection		Inspection		Inspection									
12	Ways to express indoor comfort				BMS									
13	External environ- ment conditions													
14	Economic calculation													

[a] The shaded modules are not applicable.

Thermal performance of buildings — Heat transfer via the ground — Calculation methods

1 Scope

This document provides methods of calculation of heat transfer coefficients and heat flow rates for building elements in thermal contact with the ground, including slab-on-ground floors, suspended floors and basements. It applies to building elements, or parts of them, below a horizontal plane in the bounding walls of the building situated

— at the level of the inside floor surface, for slab-on-ground floors, suspended floors and unheated basements;

NOTE 1 In some cases, external dimension systems define the boundary at the lower surface of the floor slab.

— at the level of the external ground surface, for heated basements.

This document includes calculation of the steady-state part of the heat transfer (the annual average rate of heat flow) and the part due to annual periodic variations in temperature (the seasonal variations of the heat flow rate about the annual average). These seasonal variations are obtained on a monthly basis and, except for the application to dynamic simulation programmes in Annex D, this document does not apply to shorter periods of time.

NOTE 2 Table 1 in the Introduction shows the relative position of this document within the set of EPB standards in the context of the modular structure as set out in ISO 52000-1.

2 Normative references

The following documents are referred to in text in such a way that some or all of their content constitutes requirements 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 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

ISO 14683, *Thermal bridges in building construction — Linear thermal transmittance — Simplified methods and default values*

ISO 52000-1:2017, *Energy performance of buildings — Overarching EPB assessment — Part 1: General framework and procedures*

NOTE 1 Default references to EPB standards other than ISO 52000-1 are identified by the EPB module code number and given in Annex A (normative template in Table A.1) and Annex B (informative default choice in Table B.1).

EXAMPLE EPB module code number: M5–5, or M5–5,1 (if module M5–5 is subdivided), or M5–5/1 (if reference to a specific clause of the standard covering M5–5).

NOTE 2 In this document, there are no choices in references to other EPB standards. The sentence and note above is kept to maintain uniformity between all EPB standards.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345 and ISO 52000-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
slab on ground
floor construction directly on the ground over its whole area

3.2
suspended floor
floor construction in which the lowest floor is held off the ground, resulting in an air void between the floor and the ground

Note 1 to entry: This air void, also called underfloor space or crawl space, may be ventilated or unventilated, and does not form part of the habitable space.

3.3
basement
usable part of a building that is situated partly or entirely below ground level

Note 1 to entry: This space may be heated or unheated.

3.4
equivalent thickness
<thermal resistance>thickness of ground (having the thermal conductivity of the actual ground) which has the same thermal resistance as the element under consideration

3.5
steady-state heat transfer coefficient
steady-state heat flow divided by temperature difference between internal and external environments

3.6
internal periodic heat transfer coefficient
amplitude of periodic heat flow divided by amplitude of internal temperature variation over an annual cycle

3.7
external periodic heat transfer coefficient
amplitude of periodic heat flow divided by amplitude of external temperature over an annual cycle

3.8
characteristic dimension of floor
area of floor divided by half the perimeter of floor

3.9
phase difference
period of time between the maximum or minimum of a cyclic temperature and the consequential maximum or minimum heat flow rate

3.10
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[6] and CEN/TS 16629[7]

Note 1 to entry: These three basic EPB documents were developed under a mandate given to CEN by the European Commission and the European Free Trade Association and support essential requirements of EU Directive 2010/31/EU on the energy performance of buildings. Several EPB standards and related documents are developed or revised under the same mandate.

[SOURCE: ISO 52000-1:2017, 3.5.14]

4 Symbols and subscripts

4.1 Symbols

Symbol	Quantity	Unit
A	area of floor	m^2
B	characteristic dimension of floor	m
d	total equivalent thickness	m
z	depth	m
H	steady-state heat transfer coefficient	W/K
h	height of floor surface above outside ground level	m
m	month number (m = 1 for January to m = 12 for December)	—
P	exposed perimeter	m
R	thermal resistance	$m^2 \cdot K/W$
U	thermal transmittance between internal and external environments	$W/(m^2 \cdot K)$
z	depth of basement floor below ground level	m
Φ	heat flow rate	W
λ	thermal conductivity	$W/(m \cdot K)$
δ	periodic penetration depth	m
θ	temperature	°C
Ψ	linear thermal transmittance	$W/(m \cdot K)$

4.2 Subscripts

For the purposes of this document, the subscripts given in ISO 52000-1 and the following apply.

adj	adjusted
an	annual
b	basement, below ground level; width
bg	basement, including the effect of the ground
bsf	below suspended floor
C	cooling
e	external
ed	edge
eff	effective (including effect of ground and/or basement)
f	floor

fg	ground floor, including the effect of the ground
g	ground
H	heating
ins	insulation
int	internal
m	month; middle (of building)
p	constant pressure
pe	external periodic
pi	internal periodic
sog	slab on ground
si	internal surface
se	external surface
sus	suspended
ub	unheated basement, including the effect of the ground
ve	ventilation
vi	virtual
w	wall
wf	wall/floor junction
wg	wall, including the effect of the ground
x	combined (through walls of under-floor space and by ventilation of the underfloor space)

5 Description of the method

5.1 Output

The output of this document is the thermal resistance and thermal transmittance of floors next to the ground and basements, together with coefficients that enable heat flows to be calculated on a monthly basis.

5.2 General description

Heat transfer via the ground is characterized by

— heat flow related to the area of the floor, depending on the construction of the floor,

— heat flow related to the perimeter of the floor, depending on thermal bridging at the edge of the floor, and

— annual periodic heat flow, also related to the perimeter of the floor, resulting from the thermal inertia of the ground.

The steady-state, or annual average, part of the heat transfer shall be evaluated using one of the methods described below.

a) A full three-dimensional numerical calculation, giving the result directly for the floor concerned: calculations shall be done in accordance with ISO 10211. The result is applicable only for the actual floor dimensions modelled.

b) A two-dimensional numerical calculation, using a floor that is infinitely long and has a width equal to the characteristic dimension of the floor (floor area divided by half perimeter, see 6.7.1); calculations shall be done in accordance with ISO 10211. The result is applicable to floors having the characteristic dimension that was modelled.

NOTE 1 The largest heat flows usually occur near the edges of the floor, and in most cases only small errors result from converting the three-dimensional problem to a two-dimensional problem in which the width of the building is taken as the characteristic dimension of the floor.

c) The area-related heat transfer calculated by the formulae given in this document (see Clause 7), together with the edge-related heat transfer obtained from linear thermal transmittances that are in accordance with any of the methods in ISO 14683 (numerical method, thermal bridge catalogues, manual calculation or default values).

NOTE 2 Linear thermal transmittance is calculated according to ISO 10211 or obtained from tables. ISO 13789:2017, Annex A has template for identifying sources of tabulated values of linear thermal transmittance, providing data for existing buildings, and identifying thermal bridges that can be neglected, with an informative default choice provided in Annex B.

For c), the steady-state part of the heat transfer is given by Formula (1):

$$H_g = A \cdot U + P \cdot \Psi_{wf} \tag{1}$$

where

H_g is the steady-state heat transfer coefficient via the ground, in W/K;

A is the area of floor, in m^2;

U is the thermal transmittance between internal and external environments ($U_{fg;sog}$, $U_{fg;sus}$ $U_{bg;eff}$ or U_{ub}, depending on floor type; see Table 4), in W/(m^2·K);

P is the exposed perimeter, in m;

Ψ_{wf} is the linear thermal transmittance of the wall/floor junction, in W/(m·K).

Method c) is applicable to a floor of any size or shape. U depends on floor size, but Ψ_{wf} is independent of the floor dimensions. Formula (1) is modified in the case of a heated basement (see 7.3.4) and in the case of application of Annex D (see D.1).

A template for defining whether method c) is allowed is given in Table A.2, with an informative default choice provided in Table B.2. A template for tabulated U-values is also given in Table A.2, with an informative default list in Table B.2.

5.3 Periodic coefficients

The document allows for different methods of allowing for phase differences between the annual cycle of temperature variation and heat flow (see C.1).

A template for defining which method is to be used is given in Table A.3, with an informative default choice provided in Table B.3.

6 Calculation of heat transfer via the ground

6.1 Output data

The output data are listed in Table 2.

Table 2 — Output data

Description	Symbol	Unit	Destination module (Table 1)	Validity interval	Varying
Thermal transmittance of slab on ground floor, including the effect of the ground	$U_{fg;sog}$	W/(m²·K)	M2–5	>0	No
Thermal transmittance of suspended floor, including the effect of the ground	$U_{fg;sus}$	W/(m²·K)	M2–5	>0	No
Thermal transmittance of wall of heated basement, including the effect of the ground	$U_{wg;b}$	W/(m²·K)	M2–5	>0	No
Thermal transmittance of floor of heated basement, including the effect of the ground	$U_{fg;b}$	W/(m²·K)	M2–5	>0	No
Effective thermal transmittance of whole heated basement, including the effect of the ground	$U_{bg;eff}$	W/(m²·K)	M2–5	>0	No
Thermal transmittance of unheated basement, including the effect of the ground	U_{ub}	W/(m²·K)	M2–5	>0	No
Thermal resistance of slab on ground floor	$R_{f;sog}$	m²·K/W	M2–5	>0	No
Thermal resistance of suspended floor	$R_{f;sus}$	m²·K/W	M2–5	>0	No
Thermal resistance of basement wall	$R_{w;b}$	m²·K/W	M2–5	>0	No
Thermal resistance of basement floor	$R_{f;b}$	m²·K/W	M2–5	>0	No
Effective thermal resistance of floor construction (including the effect of the ground)	$R_{f;eff}$	m²·K/W	M2–5	>0	No
Ground heat transfer coefficient for each month	$H_{g;an,m}$	W/K	M2–5	>0	Yes
Ground heat transfer coefficient for the heating season	$H_{g;H;adj}$	W/K	M2–5	>0	No
Ground heat transfer coefficient for the cooling season	$H_{g;C;adj}$	W/K	M2–5	>0	No
Thermal resistance of 0,5 m of ground (for dynamic calculations according to Annex F)	R_g	m²·K/W	M2–5	>0	No
Thermal capacity of 0,5 m of ground (for dynamic calculations according to Annex F)	κ_g	J/(m²·K)	M2–5	>0	No
Thermal resistance of virtual layer (for dynamic calculations according to Annex F)	R_{vi}	m²·K/W	M2–5	>0	No
Virtual temperature in ground for each month (for dynamic calculations according to Annex F)	θ_{vi}	°C	M2–5	—	Yes

6.2 Calculation time intervals

The calculation of periodic coefficients and heat flows apply to a time interval of one month. For other quantities the input, the method and the output data are for steady-state conditions and assumed to be independent of actual conditions, such as indoor temperature or effect of wind or solar radiation, so there is no need to consider a specific time interval length.

6.3 Input data

Tables 3, 4, 5 and 6 list identifiers for input data required for the calculation.

Table 3 — Identifiers for building geometric characteristics

Name	Symbol	Unit	Value	Range	Origin	Varying
Area of floor	A	m^2	—	≥0	—	No
Exposed perimeter	P	m	—	≥0	—	No
Length of linear thermal bridge k	l_k	m	—	≥0	—	No
Thickness of the walls of the dwelling	$d_{w;e}$	m	—	≥0	—	No
Height of the upper surface of the floor above external ground level	h	m	—	≥0	—	No
Depth of basement floor below ground level	z	m	—	≥0	—	No

Table 4 — Identifiers for building boundary conditions

Name	Symbol	Unit	Value	Range	Origin	Varying
Indoor environment temperature in the building under consideration	θ_{int}	°C	—	0 to 50	—	Yes
External air temperature	θ_e	°C	—	−50 to 50	—	Yes
Virtual temperature of the ground	$\theta_{vi,m}$	°C	—	0...∞	—	Yes

Table 5 — Identifiers for thermal characteristics of building fabric

Name	Symbol	Unit	Value	Range	Origin	Varying
Thermal transmittance of element i	U_i	W/(m²·K)	—	0 to 10	ISO 6946	No
Linear thermal transmittance associated with wall/floor junction	Ψ_k	W/(m·K)	—	0 to 10	ISO 14683 or ISO 10211	No

Table 8 lists identifiers for constants.

Table 6 — Identifiers for constants

Name	Symbol	Unit	Value	Range	Origin	Varying
Specific heat capacity of air at constant pressure	c_p	J/(kg·K) Wh/(kg·K)	1 008 0,28	—	—	No
Density of air (at 10 °C and 100 kPa pressure)	ρ	kg/m³	1,23	—	—	No

6.4 Thermal properties

6.4.1 Thermal properties of the ground

Default values are given in Table 7. If the ground type is unknown, category 2 should be used.

NOTE ISO/TR 52019-2 gives information about the range of values of ground properties.

Table 7 — Thermal properties of the ground

Category	Description	Thermal conductivity λ_g W/(m·K)	Heat capacity per volume ρc J/(m^3·K)
1	clay or silt	1,5	$3{,}0 \times 10^6$
2	sand or gravel	2,0	$2{,}0 \times 10^6$
3	homogeneous rock	3,5	$2{,}0 \times 10^6$

A template for providing properties of the ground is given in Table A.4, with an informative default choice provided in Table B.4.

6.4.2 Thermal properties of building materials

Thermal resistance values shall conform with ISO 6946. The thermal resistance of materials used below ground level should reflect the moisture and temperature conditions of the application.

NOTE The heat capacity of building materials used in floor constructions is small compared with that of the ground and is neglected.

6.4.3 Surface resistances

Values of surface resistance shall conform to ISO 6946.

The value of R_{si} is used both at the top and at the bottom of an underfloor space.

6.5 Internal temperature and climatic data

6.5.1 Internal temperature

If there are different temperatures in different rooms or spaces immediately above the floor, use a spatial average. Obtain this average by weighting the temperature of each space by the area of that space in contact with the ground.

To calculate heat flow rates, this document requires

a) annual mean internal temperature, and

b) if variations in internal temperature are to be included, amplitude of variation of internal temperature from the annual mean; this amplitude is defined as half the difference between the maximum and minimum values of the average temperatures for each month.

6.5.2 Climatic data

To calculate heat flow rates, this document requires

a) annual mean external air temperature,

b) if variations in external temperature are to be included, amplitude of variation of external air temperature from the annual mean; this amplitude is defined as half the difference between the maximum and minimum values of the average temperatures for each month, and

c) for suspended floors that are naturally ventilated, the average wind speed measured at a height of 10 m above external ground level.

If the ground surface temperature is known, this can be used in place of the external air temperature, in order to allow for effects of snow cover, solar gain on the ground surface and/or long wave radiation to clear skies. In such cases, R_{se} should be excluded from all formulae.

A template for providing ground surface temperatures is given in Table A.5, with an informative default choice provided in Table B.5.

6.6 Thermal transmittance and heat flow rate

6.6.1 Thermal transmittance

Thermal transmittances for floors and basements are related to the steady-state component of the heat transfer. Methods of calculation are given in Clause 7 for the various types of floor and basement. The formulae use the characteristic dimension of the floor and the equivalent thickness of floor insulation (see 6.7).

If the transmission heat loss coefficient for the ground is required, take this as equal to the steady-state ground heat transfer coefficient, H_g, calculated using Formula (1).

6.6.2 Thermal bridges at edge of floor

The formulae in this document are based on an isolated floor considered independently of any interaction between floor and wall. They also assume uniform thermal properties of the soil (except for effects solely due to edge insulation).

In practice, wall/floor junctions for slab-on-ground floors do not correspond with this ideal, giving rise to thermal bridge effects. These shall be allowed for in calculations of the total heat loss from a building, by using a linear thermal transmittance, Ψ_{wf}.

NOTE The linear thermal transmittance depends on the system being used for defining building dimensions (see ISO 13789).

The total heat loss from a building is then calculated on the basis of a separating plane

— at the level of the inside floor surface for slab-on-ground floors, suspended floors and unheated basements, or

— at the level of the outside ground surface for heated basements.

NOTE In some cases, external dimension systems define the boundary at the lower surface of the floor slab.

The thermal transmittance of elements above the separating plane should be assessed in accordance with appropriate standards, such as ISO 6946.

6.6.3 Calculation of heat flow rate

Heat transfer via the ground can be calculated on an annual basis using only the steady-state ground heat transfer coefficient, or on a seasonal or monthly basis using additional periodic coefficients that take account of the thermal inertia of the ground (see 5.2). The relevant formulae for periodic coefficients are given in Annex C.

6.6.4 Effect of ground water

Ground water has a negligible effect on the heat transfer, unless it is at a shallow depth and has a high flow rate. Such conditions are rarely encountered and in most cases no allowance should be made for the effect of ground water.

A template for providing ground surface temperatures is given in Table A.5, with an informative default choice provided in Table B.5.

When the depth of the water table below ground level and the rate of ground water flow are known, the steady-state ground heat transfer coefficient, H_g, may be multiplied by a factor, G_w.

NOTE ISO/TR 52019-2 contains illustrative values of G_w.

A template for defining when the effect of flowing ground water is to be included is given in Table A.6, with an informative default choice provided in Table B.6.

6.6.5 Special cases

The methods in this document are also applicable to the following situations, with the modifications described in the relevant annex:

— heat flow rates for edge and central regions of a floor (see Annex E);

— application to dynamic simulation programs (see Annex F).

NOTE For the floors of cold stores and slab-on-ground floors with an embedded heating system, see ISO/TR 52019-2.

6.7 Parameters used in the calculations

6.7.1 Characteristic dimension of floor

To allow for the three-dimensional nature of heat flow within the ground, the formulae in this document are expressed in terms of the "characteristic dimension" of the floor, B, defined as the area of the floor divided by half the perimeter:

$$B = \frac{A}{0{,}5 \times P} \tag{2}$$

where

B is the characteristic dimension of floor, in m;

A is area of floor, in m^2;

P is the exposed perimeter, in m.

NOTE For an infinitely long floor, B is the width of the floor; for a square floor, B is half the length of one side.

Special foundation details, e.g. edge insulation of the floor, are treated as modifying the heat flow at the perimeter.

In the case of basements, B is calculated from the area and perimeter of the floor of the basement, and the heat flow from the basement includes an additional term related to the perimeter and the depth of the basement floor below ground level.

In this document, P is the total length of external wall dividing the heated building from the external environment or from an unheated space outside the insulated fabric. Therefore,

— for a complete building, P is the total perimeter of the building and A is its total ground-floor area,

— to calculate the heat loss from part of a building (e.g. for each individual dwelling in a row of terraced houses), P includes the lengths of external walls separating the heated space from the external environment and excludes the lengths of walls separating the part under consideration from other heated parts of the building, while A is the ground-floor area under consideration, and

— unheated spaces outside the insulated fabric of the building (such as porches, attached garages or storage areas) are excluded when determining P and A (but the length of the wall between the heated building and the unheated space is included in the perimeter; the ground heat losses are assessed as if the unheated spaces were not present).

6.7.2 Equivalent thickness

The concept of “equivalent thickness” is introduced to simplify the expression of the thermal transmittances.

A thermal resistance is represented by its equivalent thickness, which is the thickness of ground that has the same thermal resistance. In this document,

— d_f is the equivalent thickness for floors, and

— $d_{w;b}$ is the equivalent thickness for walls of basements below ground level.

The steady-state ground heat transfer coefficients are related to the ratio of equivalent thickness to characteristic floor dimension, and the periodic heat transfer coefficients are related to the ratio of equivalent thickness to periodic penetration depth.

7 Calculation of thermal transmittances

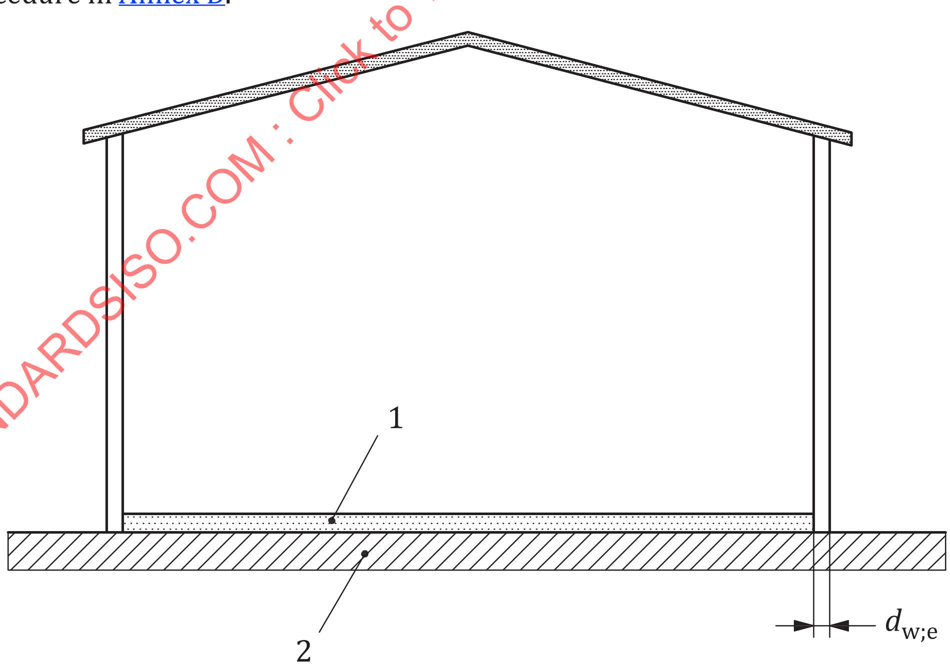
7.1 Slab-on-ground floor

Slab-on-ground floors include any floor consisting of a slab in contact with the ground over its whole area, whether or not supported by the ground over its whole area, and situated at or near the level of the external ground surface (see Figure 1). This floor slab can be

— uninsulated, or

— evenly insulated (above, below or within the slab) over its whole area.

If the floor has horizontal and/or vertical edge insulation, the thermal transmittance shall be corrected using the procedure in Annex D.



Key

1 floor slab

2 ground

$d_{w;e}$ thickness of external walls

Figure 1 — Schematic diagram of slab-on-ground floor

The thermal transmittance depends on the characteristic dimension of the floor, B [see 6.7.1 and Formula (2)], and the total equivalent thickness, d_f (see 6.7.2), defined by Formula (3):

$$d_f = d_{w;e} + \lambda_g \cdot (R_{si} + R_{f;sog} + R_{se}) \tag{3}$$

where

d_f is the total equivalent thickness, in m;

$d_{w;e}$ is the full thickness of the walls, including all layers, in m;

λ_g is the thermal conductivity of the ground, in W/(m·K);

$R_{f;sog}$ is the thermal resistance of the floor slab, including that of any all-over insulation layers above, below or within the floor slab, and that of any floor covering, in m²·K/W;

R_{si} is the thermal resistance of internal surface, in m²·K/W;

R_{se} is the thermal resistance of external surface, in m²·K/W.

The thermal resistance of dense concrete slabs and thin floor coverings may be neglected. Hard core below the slab is assumed to have the same thermal conductivity as the ground, and its thermal resistance should not be included.

Calculate the thermal transmittance using either Formula (4) or Formula (5), depending on the thermal insulation of the floor.

If $d_f < B$ (uninsulated and moderately insulated floors),

$$U_{fg;sog} = \frac{2 \cdot \lambda_g}{\pi \cdot B + d_f} \cdot \ln\left(\frac{\pi \cdot B}{d_f} + 1\right) \tag{4}$$

If $d_f \geq B$ (well-insulated floors),

$$U_{fg;sog} = \frac{\lambda_g}{0,457 \times B + d_f} \tag{5}$$

For well-insulated floors, it can be written alternatively as:

$$U_{fg;sog} = \frac{1}{\left(R_{si} + R_f + R_{se} + d_{w;e} / \lambda_g\right) + R_{g;eff}} \tag{6}$$

where

$R_{g;eff}$ is the effective thermal resistance of the ground, in m²·K/W, given by:

$$R_{g;eff} = \frac{0,457 \times B}{\lambda_g} \tag{7}$$

The thermal transmittance shall be rounded to two significant figures if presented as the final result. Intermediate calculations shall be undertaken with at least three significant figures.

NOTE The thermal transmittance can be small for large floors, so that more decimal places are needed.

The steady-state ground heat transfer coefficient between internal and external environments is obtained using Formula (1).

7.2 Suspended floor

A suspended floor is any type of floor held off the ground, e.g. timber or beam-and-block (see Figure 2). This clause deals with the conventional design of suspended floor in which the underfloor space is naturally ventilated with external air. For mechanical ventilation of the underfloor space, or if the ventilation rate is specified, see Annex G.

The thermal transmittance is given by Formula (8):

$$\frac{1}{U_{\text{fg;sus}}} = \frac{1}{U_{\text{f;sus}}} + \frac{1}{U_{\text{g}} + U_{\text{x}}} \tag{8}$$

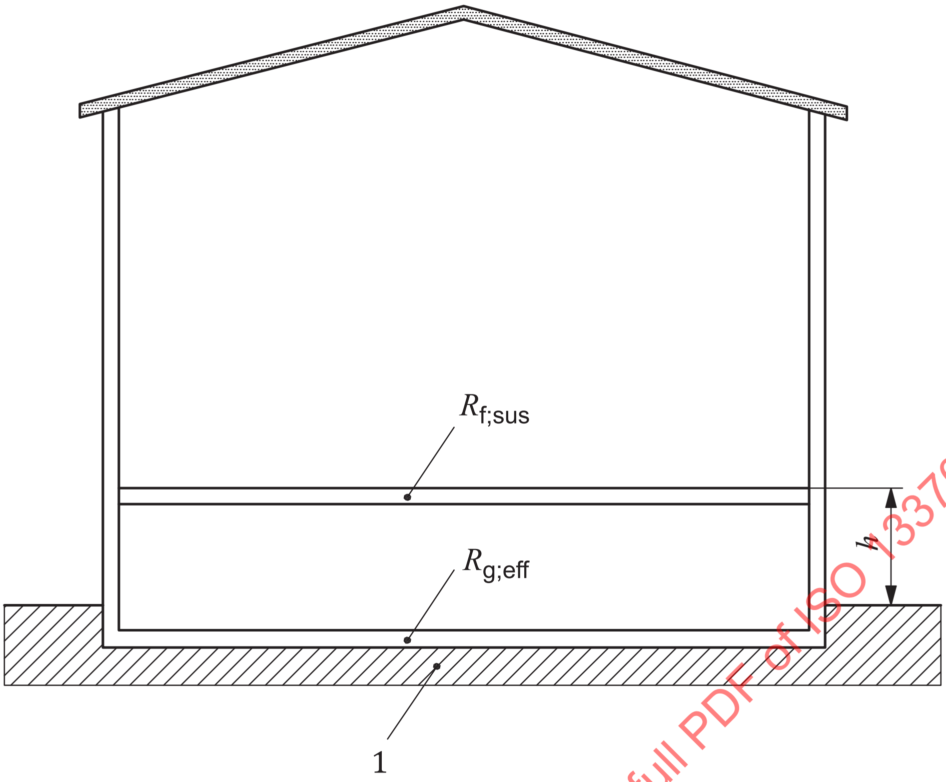
where

$U_{\text{f;sus}} = \dfrac{1}{R_{\text{f;sus}}}$ is the thermal transmittance of suspended part of floor (between the internal environment and the underfloor space), in W/(m²·K);

$R_{\text{f;sus}}$ is the total thermal resistance of the suspended part of the floor, in m²·K/W, calculated in accordance with ISO 6946 allowing for any bridged layers in the floor construction and using surface resistances in accordance with 6.4.3;

$U_{\text{g}} = \dfrac{1}{R_{\text{g;eff}}}$ is the thermal transmittance for heat flow through the ground, in W/(m²·K);

U_{x} is an equivalent thermal transmittance between the underfloor space and the outside accounting for heat flow through the walls of the underfloor space and by ventilation of the underfloor space, in W/(m²·K).



Key

1 Ground

h height of floor surface above outside ground level

$R_{f;sus}$ thermal resistance of floor construction

$R_{g;eff}$ effective thermal resistance of ground

Figure 2 — Schematic diagram of suspended floor

The calculation of $U_{f;sus}$ shall include the effect of any thermal bridging. It may be calculated in accordance with ISO 6946 or by a numerical method. In the case of a low-emissivity surface on the lower side of the floor, the surface resistance may be modified using the procedure given in ISO 6946. Surface resistances for downwards heat flow apply in the case of a heated building, and surface resistances for upwards heat flow apply in the case of a cooled building.

Calculate U_g by means of Formulae (2), (9) and (10):

$$d_g = d_{w;e} + \lambda_g \cdot \left(R_{si} + R_{f;ins} + R_{se}\right) \tag{9}$$

$$U_g = \frac{2 \cdot \lambda_g}{\pi \cdot B + d_g} \cdot \ln\left(\frac{\pi \cdot B}{d_g} + 1\right) \tag{10}$$

where

$R_{f,ins}$ is the thermal resistance of any insulation on the base of the underfloor space, in m²·K/W;

d_g is the equivalent thickness for the ground below the suspended floor, in m²·K/W.

If the underfloor space extends to an average depth of more than 0,5 m below ground level, calculate U_g according to Formula (G.2).

If edge insulation is applied around the base of the underfloor space, modify U_g according to Formula (D.3).

Obtain U_x from Formula (11):

$$U_x = 2 \times \frac{h \cdot U_w}{B} + 1\,450 \times \frac{\varepsilon \cdot v \cdot f_w}{B} \tag{11}$$

where

h is the height of the upper surface of the floor above external ground level, in m;

U_w is the thermal transmittance of walls of underfloor space above ground level, in W/(m²·K), calculated in accordance with ISO 6946;

ε is the area of ventilation openings per perimeter length of underfloor space, in m²/m;

v is the average wind speed at 10 m height, in m/s;

f_w is the wind shielding factor.

If h varies around the perimeter of the floor, its average value is used in Formula (11).

Annex G gives the formulae for the calculation of the average temperature in the underfloor space.

The wind shielding factor relates the wind speed at 10 m height (assumed unobstructed) to that near ground level, allowing for the shielding by adjacent buildings, etc. Representative values are given in Table 8.

Table 8 — Values of the wind shielding factor

Category	Location	Example	Wind shielding factor f_w
1	Sheltered	City centre	0,02
2	Average	Suburban	0,05
3	Exposed	Rural	0,10

The steady-state ground heat transfer coefficient between internal and external environments is obtained using Formula (1).

A template for defining wind shielding factors is given in Table A.7, with an informative default choice provided in Table B.7.

7.3 Heated basement

7.3.1 General

The procedures given for basements apply to buildings in which part of the habitable space is below ground level (see Figure 3). The formulae given in 7.3.2 to 7.3.4 apply to heat transfer between the internal environment of a heated basement and the external environment. The basis is similar to that for the slab-on-ground, but allowing for

— the depth, z, of the floor of the basement below ground level, and

— the possibility of different insulation levels being applied to the walls of the basement and to the floor of the basement.

If z varies round the perimeter of the building, its mean value is used in the calculations.

NOTE 1 If $z = 0$, the formulae reduce to those given in 7.1 for the slab-on-ground.

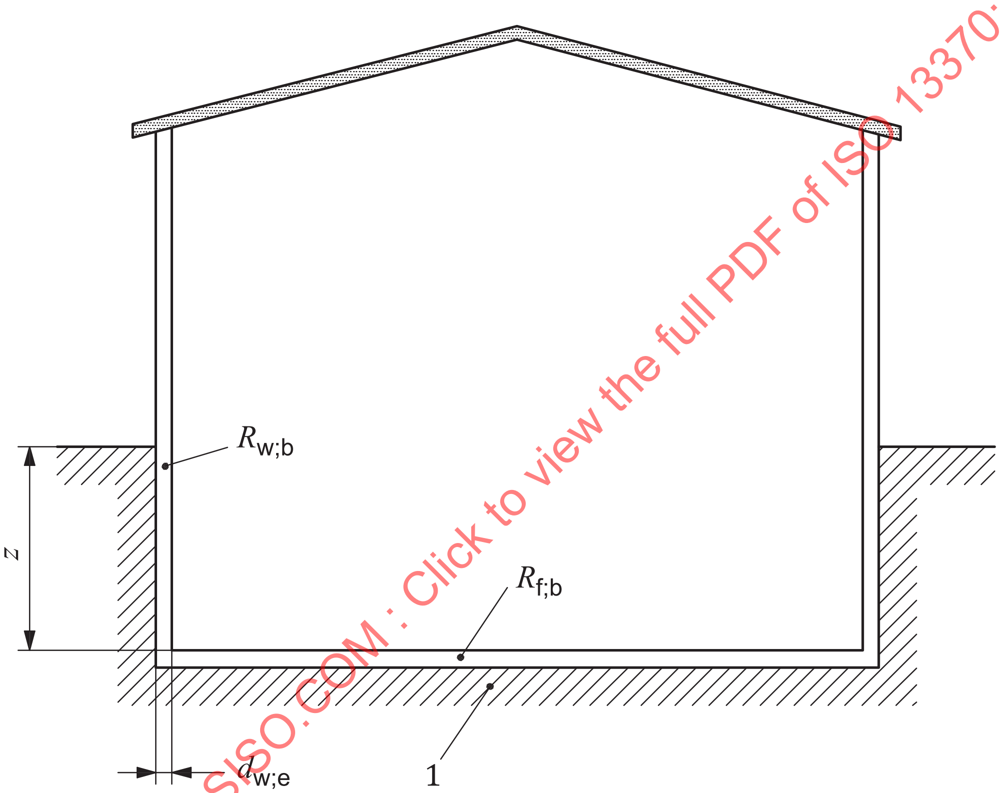
This document does not directly cover the case of a building having partly a floor on the ground and partly a basement. However, an approximation to the total heat loss via the ground from such a building can be obtained by treating the building as if it had a basement over its whole area with depth equal to half the actual depth of the basement part.

A template for defining whether this approximation is allowed is given in Table A.8, with an informative default choice provided in Table B.8.

NOTE 2 Basements that are partly heated are treated in 7.5.

The procedures described give the total heat flow from the basement through the ground, i.e. through the floor of the basement and through the walls of the basement below ground level.

NOTE 3 The parts of the walls above ground level are assessed by their thermal transmittance calculated in accordance with ISO 6946.



Key

1 ground

$R_{f;b}$ thermal resistance of floor construction

$R_{w,b}$ thermal resistance of walls of the basement, including all layers

$d_{w,e}$ thickness of external walls

z depth of basement floor below ground level

Figure 3 — Schematic diagram of building with heated basement

7.3.2 Basement floor

To determine $U_{f;b}$ calculate the characteristic dimension for the basement floor using Formula (2), and include any insulation of the basement floor in the total equivalent thickness, $d_{w;e}$, given by Formula (12):

$$d_f = d_{w;e} + \lambda_g \cdot \left(R_{si} + R_{f;b} + R_{se}\right) \tag{12}$$

where

d_f is the total equivalent thickness, in m;

$d_{w,e}$ is the full thickness of the walls of the building at ground level, including all layers, in m;

$R_{f;b}$ is the thermal resistance of the floor slab, including that of any all-over insulation layers above, below or within the floor slab, and that of any floor covering, in m²·K/W;

R_{si} is the thermal resistance of internal surface, in m²·K/W;

R_{se} is the thermal resistance of external surface, in m2·K/W;

λ_g is the thermal conductivity of the ground, in W/(m·K).

The thermal resistance of dense concrete slabs and thin floor coverings may be neglected. Hard core below the slab is assumed to have the same thermal conductivity as the ground and its thermal resistance should be neglected.

Use either Formula (13) or Formula (14), depending on the thermal insulation of the basement floor.

If $(d_f + 0{,}5 \times z) < B$ (uninsulated and moderately insulated basement floors),

$$U_{fg;b} = \frac{2 \cdot \lambda_g}{\pi \cdot B + d_f + 0{,}5 \times z} \cdot \ln\left(\frac{\pi \cdot B}{d_f + 0{,}5 \times z} + 1\right) \tag{13}$$

If $(d_f + 0{,}5 \times z) \geq B$ (well-insulated basement floors),

$$U_{fg;b} = \frac{\lambda_g}{0{,}457 \times B + d_f + 0{,}5 \times z} \tag{14}$$

7.3.3 Basement walls

$U_{wg;b}$ depends on total equivalent thickness for the basement walls, $d_{w;b}$, given by Formula (15):

$$d_{w;b} = \lambda_g \cdot \left(R_{si} + R_{w;b} + R_{se}\right) \tag{15}$$

where $R_{w;b}$ is the thermal resistance of the walls of the basement, including all layers, and the other symbols are defined in Clause 4.

Obtain $U_{wg;b}$ from Formula (16):

$$U_{wg;b} = \frac{2 \cdot \lambda_g}{\pi \cdot z} \cdot \left(1 + \frac{0{,}5 \times d_f}{d_f + z}\right) \cdot \ln\left(\frac{z}{d_{w;b}} + 1\right) \tag{16}$$

The formula for $U_{wg;b}$ involves both $d_{w;b}$ and d_f. It is valid for $d_{w;b} \geq d_f$, which is usually the case. If, however, $d_{w;b} < d_f$ then d_f should be replaced by $d_{w;b}$ in Formula (16).

7.3.4 Heat transfer from whole basement

The effective thermal transmittance characterizing the whole of the basement in contact with the ground is

$$U_{bg;eff} = \frac{A \cdot U_{f;b} + z \cdot P \cdot U_{w;b}}{A + z \cdot P} \tag{17}$$

Formula (1) for steady-state ground heat transfer coefficient between internal and external environments is modified to include the basement and H_g is given by Formula (18).

$$H_g = A \cdot U_{fg;b} + z \cdot P \cdot U_{wg;b} + P \cdot \Psi_{w;f} \tag{18}$$

NOTE Formula (18) gives the heat flow from the whole basement. The heat transfers through the floor and walls of the basement are interlinked, and for this reason, the first two terms in Formula (18), for the heat flow through the floor and walls respectively, are approximations.

7.4 Unheated basement

The formulae given in this subclause apply to heat transfer between the internal environment and the external environment via an unheated basement ventilated from the outside.

The thermal transmittance between internal and external environments, U_{ub}, is given by Formula (19):

$$\frac{1}{U_{ub}} = \frac{1}{U_{f;sus}} + \frac{A}{\left(A \cdot U_{fg;b}\right) + \left(z \cdot P \cdot U_{wg;b}\right) + \left(h \cdot P \cdot U_{w}\right) + \left(c_p \cdot \rho \cdot n \cdot V\right)} \tag{19}$$

where

$U_{f;sus}$ is the thermal transmittance of the floor (between the internal environment and the basement), in W/(m²·K);

U_w is the thermal transmittance of the walls of the basement above ground level in W/(m²·K);

h is the height of the basement walls above ground level, in m;

c_p is the specific heat capacity of air at constant pressure, in Wh/(kg·K);

ρ is the density of air, in kg/m³;

n is the ventilation rate of the basement, in air changes per hour;

V is the air volume of the basement, in m³.

In the absence of specific information, a value of n = 0,3 air changes per hour may be used.

Calculate $U_{f;sus}$ and U_w in accordance with ISO 6946.

Calculate $U_{fg;b}$ and $U_{wg;b}$ in accordance with 7.3.

NOTE The average temperature in the basement can be calculated by the method in Annex G.

The steady-state ground heat transfer coefficient between internal and external environments is obtained using Formula (1).

7.5 Partly heated basement

The heat flow rates for partly heated basements are calculated by the following procedure:

a) calculate the heat flow rate for a fully heated basement;

b) calculate the heat flow rate for an unheated basement;

c) combine the heat flow rates in a) and b) in proportion to the areas of heated and unheated parts of the basement in contact with the ground in order to obtain the heat flow rate for a partly heated basement.

7.6 Effective thermal resistance of floor construction

In transient methods for the calculation of heat flows or temperatures in buildings using a time interval of one hour or less, the effective thermal resistance of the floor construction (including the effect of the ground) is calculated as follows:

$$R_{f;eff} = \frac{1}{U} - R_{si} \tag{20}$$

where

$R_{f;eff}$ is the effective thermal resistance of the floor construction (including the effect of the ground), in $m^2 \cdot K/W$;

U is the thermal transmittance of the floor as calculated in 7.1, 7.2, 7.3 or 7.4, in $W/(m^2 \cdot K)$.

NOTE *U* includes the annual average effect of ground.

Annex A
(normative)

Input and method selection data sheet — Template

A.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other documents.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section "Introduction" of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

A.2 References

The references, identified by the module code number, are given in Table A.1.

Table A.1 — References

Reference	Reference document[a]	
	Number	Title
Mx-y[b]	...	...
	...	...

[a] If a reference comprises more than one document, the references may be differentiated.

[b] In this document, there are no choices in references to other EPB standards. The table is kept to maintain uniformity between all EPB standards.

A.3 Selection of methods

Table A.2 — Choice of calculation methods (see 5.2)

Item	Choice
Method c) in 5.2 allowed?	Yes/No
If yes, method for thermal bridging	Numerical calculation Thermal bridge catalogue Manual calculation Default values
If yes, tabulated *U*-values (as input for Formula (1) allowed for existing buildings?	If yes, provide a list with construction types and corresponding *U*-values, for instance as function of year of construction.

Table A.3 — Allowing for phase difference (see 5.3 and C.1)

Item	Choice
Method of calculation of heat flow rate via the ground	One of: a) calculation of the ground heat flow rate separately for each month b) calculation of the average ground heat flow rate during the heating season c) calculation of the annual average ground heat flow.

A.4 Input data and choices

Table A.4 — Thermal properties of the ground (see 6.4.1)

Item	Choice
Differentiation in ground category	Yes/No If yes, specify the procedure to classify the soil category (free text). If no, give soil category (1, 2 or 3; see Table 9).
Thermal properties of the ground	Either: a) specific values, which can be given for different locations, or b) reference to Table 9.

Table A.5 — Ground surface temperatures (see 6.5.2)

Item	Choice
Ground surface temperature	Either: a) specific values, which can be given for different locations, or b) use external air temperature.

Table A.6 — Flowing ground water (see 6.6.4)

Item	Choice
Flowing ground water	Either: a) no allowance for flowing ground water, or b) details of locations where flowing ground water is to be taken into account together with the water table depth, mean drift velocity of the ground water and a reference to ISO/TR 52019-2 or to an alternative calculation method.

Table A.7 — Wind shielding factors (see 7.2)

Item	Choice
Differentiation in location category (for wind shielding factors)	Yes/No If yes, specify the procedure to classify the location category (free text). If no, give the location category (1, 2 or 3; see Table 10).
Wind shielding factors	Either: a) specific values, which can be given for different locations, or b) reference to Table 10.

Table A.8 — Partial basements (see 7.3.1)

Item	Choice
Approximation for partial basements in 7.3.1 allowed?	Yes/No

Table A.9 — Month number (see C.2)

Item	Choice
Month number with minimum external temperature	Value (whole month of fraction of a month). Can be given for different locations.

Table A.10 — Edge insulation (see D.1)

Item	Choice
Procedures in Annex D allowed for edge insulation of floor slab?	Yes/No

Annex B
(informative)

Input and method selection data sheet — Default choices

B.1 General

The template in Annex A of this document shall be used to specify the choices between methods, the required input data and references to other standards.

NOTE 1 Following this template is not enough to guarantee consistency of data.

NOTE 2 Informative default choices are provided in Annex B. Alternative values and choices can be imposed by national/regional regulations. If the default values and choices of Annex B are not adopted because of the national/regional regulations, policies or national traditions, it is expected that:

— national or regional authorities prepare data sheets containing the national or regional values and choices, in line with the template in Annex A; or

— by default, the national standards body will add or include a national annex (Annex NA) to this document, in line with the template in Annex A, giving national or regional values and choices in accordance with their legal documents.

NOTE 3 The template in Annex A is applicable to different applications (e.g., the design of a new building, certification of a new building, renovation of an existing building and certification of an existing building) and for different types of buildings (e.g., small or simple buildings and large or complex buildings). A distinction in values and choices for different applications or building types could be made:

— by adding columns or rows (one for each application), if the template allows;

— by including more than one version of a table (one for each application), numbered consecutively as a, b, c, ... For example: Table NA.3a, Table NA.3b;

— by developing different national/regional data sheets for the same standard. In case of a national annex to the standard these will be consecutively numbered (Annex NA, Annex NB, Annex NC, ...).

NOTE 4 In the section "Introduction" of a national/regional data sheet information can be added, for example about the applicable national/regional regulations.

NOTE 5 For certain input values to be acquired by the user, a data sheet following the template of Annex A, could contain a reference to national procedures for assessing the needed input data. For instance, reference to a national assessment protocol comprising decision trees, tables and pre-calculations.

The shaded fields in the tables are part of the template and consequently not open for input.

B.2 References

The references, identified by the module code number, are given in Table B.1.

Table B.1 — References

Reference	Reference document[a]	
	Number	Title
Mx-y[b]	...	...
	...	...

[a] If a reference comprises more than one document, the references may be differentiated.

[b] In this document, there are no choices in references to other EPB standards. The table is kept to maintain uniformity between all EPB standards.

B.3 Selection of methods

Table B.2 — Choice of calculation methods (see 5.2)

Item	Choice
Method c) in 5.2 allowed?	Yes
If yes, method for thermal bridging?	Default values (ISO 14683)
If yes, tabulated *U*-values (as input for Formula (1) allowed for existing buildings?	A list with construction types and corresponding *U*-values, for instance as function of year of construction, depends on the national/regional building tradition and thermal or energy performance requirements at the year of construction.

Table B.3 — Allowing for phase difference (see 5.3 and C.1)

Item	Choice
Method of calculation of heat flow rate through the ground	Calculation of the annual average ground heat flow

B.4 Input data and choices

Table B.4 — Thermal properties of the ground (see 6.4.1)

Item	Choice
Differentiation in ground category	No Use category 2 in Table 9
Thermal properties of the ground	Use Table 9

Table B.5 — Ground surface temperatures (see 6.5.2)

Item	Choice
Ground surface temperature	Use external air temperature

Table B.6 — Flowing ground water (see 6.6.4)

Item	Choice
Flowing ground water	No allowance for flowing ground water

Table B.7 — Wind shielding factors (see 7.2)

Item	Choice
Differentiation in location category (for wind shielding factors)	No Use category 2 in Table 10
Wind shielding factors	Use Table 10

Table B.8 — Partial basements (see 7.3.1)

Item	Choice
Approximation for partial basements in 7.3.1 allowed?	Yes

Table B.9 — Month number (see C.2)

Item	Choice
Month number with minimum external temperature	τ = 1 in the northern hemisphere and τ = 7 in the southern hemisphere.
NOTE τ = 1 assumes the minimum temperature occurs in the middle of January and the maximum temperature in the middle of July, and τ = 7 assumes the converse. This is a good approximation for many climates.	

Table B.10 — Edge insulation (see D.1)

Item	Choice
Procedures in Annex D allowed for edge insulation of floor slab?	Yes

Annex C
(normative)

Calculation of ground heat flow rate

C.1 Methods of calculation

Three methods of calculating the heat flow rate, Φ, are provided:

a) calculation of the ground heat flow rate separately for each month (see C.2 and C.3);

b) calculation of the average ground heat flow rate during the heating season and cooling season (see C.4);

c) calculation of the annual average ground heat flow rate (see C.5).

A template for defining which method is to be used is given in Table A.3, with an informative default choice provided in Table B.3.

NOTE The appropriate method can depend on the purpose of the calculation and the accuracy to which it is necessary or appropriate to evaluate the heat flow rate.

C.2 Monthly heat flow rate using sinusoidal temperature variations

To allow for the effect of the large thermal inertia of the ground, the heat transfer is represented by a steady-state, or average component, together with an annual periodic component. The steady-state component is related to the difference between annual average internal temperature and annual average external temperature. The periodic component is related to the amplitude of the variation of the internal and external temperatures about their respective average values.

The internal and external temperatures are assumed to vary sinusoidally about their annual average values in the following form:

$$\theta_{\mathrm{int},m} = \bar{\theta}_{\mathrm{int}} - \hat{\theta}_{\mathrm{int}} \cdot \cos\left[2\pi \cdot \left(\frac{m-\tau}{12}\right)\right] \tag{C.1}$$

$$\theta_{\mathrm{e},m} = \bar{\theta}_{\mathrm{e}} - \hat{\theta}_{\mathrm{e}} \cdot \cos\left[2\pi \cdot \left(\frac{m-\tau}{12}\right)\right] \tag{C.2}$$

where

$\theta_{\mathrm{int},m}$ is the monthly mean internal temperature for month m, in °C;

$\bar{\theta}_{\mathrm{int}}$ is the annual average internal temperature, in °C;

$\hat{\theta}_{\mathrm{int}}$ is the amplitude of variations in monthly mean internal temperature, in K (as defined in 6.5.1);

$\theta_{\mathrm{e},m}$ is the monthly mean external temperature for month m, in °C;

$\bar{\theta}_{\mathrm{e}}$ is the annual average external temperature, in °C;

$\hat{\theta}_e$ is the amplitude of variations in monthly mean external temperature, in K (as defined in 6.5.2);

m is the month number (m = 1 for January to m = 12 for December);

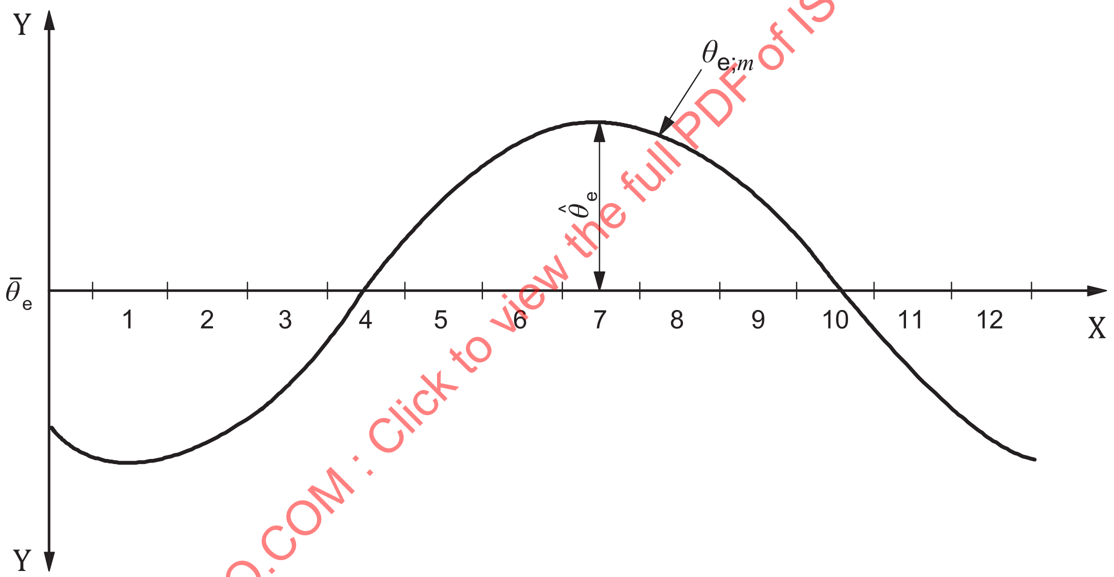
τ is the month number in which the minimum external temperature occurs (if appropriate, τ may be expressed as a decimal number).

τ should be assessed from consideration of the average external temperature for each month; shorter term fluctuations should not be included. It can be based on climatological information for the country or location concerned, expressed in whole months or a fraction of a month depending on the information available.

A template for defining wind shielding factors is given in Table A.7, with the default provided in Table B.7

NOTE 1 Only the annual average temperature and the annual amplitude are required for calculations. These quantities can be derived from monthly values.

Figure C.1 illustrates the definitions of $\bar{\theta}_e$ and $\hat{\theta}_e$. The same applies to the internal temperature.



Key

X month number, m (m = 1 for January to m = 12 for December)

Y temperature, θ

$\bar{\theta}_e$ annual average external temperature

$\hat{\theta}_e$ amplitude of variations in monthly mean external temperature

$\theta_{e;m}$ monthly mean external temperature for month m

Figure C.1 — Illustration of the variation of external temperature over a year (in northern hemisphere)

The average rate of heat flow in month m is then given by

$$\Phi_m = H_g \cdot \left(\bar{\theta}_{int} - \bar{\theta}_e\right) - H_{pi} \cdot \hat{\theta}_{int} \cdot \cos\left(2\pi \cdot \frac{m - \tau + \alpha}{12}\right) + H_{pe} \cdot \hat{\theta}_e \cdot \cos\left(2\pi \cdot \frac{m - \tau - \beta}{12}\right) \quad \text{(C.3)}$$

where

Φ_m is the average rate of heat flow in month m, in W;

H_g is the steady-state ground heat transfer coefficient, in W/K;

H_{pi} is the internal periodic heat transfer coefficient, in W/K;

H_{pe} is the external periodic heat transfer coefficient, in W/K;

$\bar{\theta}_{int}$ is the annual average internal temperature, in °C;

$\hat{\theta}_{int}$ is the amplitude of variations in monthly mean internal temperature, in K;

$\bar{\theta}_e$ is the annual average external temperature, in °C;

$\hat{\theta}_e$ is the amplitude of variations in monthly mean external temperature, in K;

α is the time lead of the heat flow cycle compared with that of the internal temperature, in months;

β is the time lag of the heat flow cycle compared with that of the external temperature, in months;

τ is the month number in which the minimum external temperature occurs.

H_{pi} and H_{pe} include the effect of thermal bridging at the floor edge. If they are calculated without the effect of edge-related heat transfer, a term $P\Psi_g$ shall be added to each of them (see 5.2).

NOTE 2 The periodic heat flow cycle leads the internal temperature variation and lags the external temperature variation. In this document, α and β are both positive numbers; the lead/lag is taken into account in the way Formula (C.3) is written.

For detailed calculation of H_{pe}, see ISO 10211.

Annex H gives practical formulae to calculate the coefficients H_{pi} and H_{pe} and the phase differences α and β.

Formula (C.3) assumes that the annual variation of internal temperature is such that θ_{int} is lower in winter than in summer. If the reverse applies, θ_{int} should be taken as negative.

NOTE 3 For calculations based on an assumption of constant internal temperature, $\theta_{int} = 0$ and H_{pi} need not be considered.

C.3 Monthly heat flow rate using monthly average temperatures

The monthly heat flow rate is calculated by

$$\Phi_m = U \cdot A \cdot \left(\bar{\theta}_{int} - \bar{\theta}_e\right) + P \cdot \Psi_{wf} \cdot \left(\theta_{int,m} - \theta_{e,m}\right) - H_{pi} \cdot \left(\bar{\theta}_{int} - \theta_{int,m}\right) + H_{pe} \cdot \left(\bar{\theta}_e - \theta_{e,m}\right) \quad \text{(C.4)}$$

where it is assumed that the phase differences α and β (see C.2) are zero and where U and A refer to the constructions in contact with the ground.

C.4 Average heat flow rate over heating season or cooling season

For seasonal heat transfer calculations, the effect of the phase difference between the heat flow and the temperature variations can usually be ignored. The average rate of ground heat flow over a heating season is then determined from the average of the cosine terms in Formula (C.3) over the heating season:

$$\bar{\Phi} = H_{\mathrm{g}} \cdot \left(\bar{\theta}_{\mathrm{int}} - \bar{\theta}_{\mathrm{e}}\right) - \gamma \cdot H_{\mathrm{pi}} \cdot \hat{\theta}_{\mathrm{int}} + \gamma \cdot H_{\mathrm{pe}} \cdot \hat{\theta}_{\mathrm{e}} \qquad \text{(C.5)}$$

where the value of γ, which depends on the length of the heating season, is given by Formula (C.6):

$$\gamma = \frac{12}{n \cdot \pi} \cdot \sin\left(\frac{n \cdot \pi}{12}\right) \qquad \text{(C.6)}$$

where n is the number of months in the heating season.

Formula (C.5) assumes that the annual variation of internal temperature is such that θ_{i} is lower in winter than in summer. If the reverse applies, $\hat{\theta}_{\mathrm{int}}$ should be taken as negative.

NOTE For calculations based on an assumption of constant internal temperature, $\hat{\theta}_{\mathrm{i}} = 0$ and H_{pi} need not be considered.

The use of Formula (C.5) is appropriate for heat loss calculations made on a seasonal, rather than a monthly, basis.

Formula (C.5) can also be used for heat loss calculations made on a monthly basis, in cases where the variation in ground losses between months is not required. This has the effect of treating the ground losses as a constant term, thus overestimating these losses at the ends of the heating season and underestimating the losses at the middle of the heating season.

The average rate of heat flow over the cooling season is calculated similarly:

$$\bar{\Phi} = H_{\mathrm{g}} \cdot \left(\bar{\theta}_{\mathrm{int}} - \bar{\theta}_{\mathrm{e}}\right) + \gamma \cdot H_{\mathrm{pi}} \cdot \hat{\theta}_{\mathrm{int}} - \gamma \cdot H_{\mathrm{pe}} \cdot \hat{\theta}_{\mathrm{e}} \qquad \text{(C.7)}$$

with γ from Formula (C.6) using the number of months in the cooling season for n.

C.5 Annual average heat flow rate

If $\hat{\theta}_{\mathrm{int}}$, $\hat{\theta}_{\mathrm{e}}$ or the length of the heating season is not known, or if the ground losses are required only approximately, the ground heat flow rate can be taken as a constant term equal to the steady-state component:

$$\bar{\Phi} = H_{\mathrm{g}} \cdot \left(\bar{\theta}_{\mathrm{int}} - \bar{\theta}_{\mathrm{e}}\right) \qquad \text{(C.8)}$$

This is often an adequate approximation, especially if the heating season is long or if $\hat{\theta}_{\mathrm{i}}$ and $\hat{\theta}_{\mathrm{e}}$ have opposite effects on the heat flow.

C.6 Maximum monthly heat flow rate

The maximum monthly heat flow rate is given by

$$\Phi_{\mathrm{max}} = H_{\mathrm{g}} \cdot \left(\bar{\theta}_{\mathrm{int}} - \bar{\theta}_{\mathrm{e}}\right) + H_{\mathrm{pe}} \cdot \hat{\theta}_{\mathrm{e}} \qquad \text{(C.9)}$$

NOTE This expression corresponds to a constant internal temperature and the maximum contribution from the external temperature variation.

C.7 Monthly ground heat transfer coefficient as input for monthly calculations of the thermal balance in a building

NOTE 1 The quantities in this sub-clause are for use in the monthly calculation method of ISO 52016-1. See Annex F for input quantities for the hourly calculation method in ISO 52016-1.

The ground heat transfer coefficient, $H_{g;an;m}$, in month m is given by:

$$H_{g;an;m} = \frac{\Phi_m}{\overline{\theta}_{int} - \overline{\theta}_e} \tag{C.10}$$

NOTE 2 The annual average temperature difference is used in Formula (C.10) because the difference between the monthly internal and external temperatures can be zero. $H_{g;an,m}$ is intended to be used with the difference between the internal temperature in month m and the annual average external temperature.

Seasonal values adjusted to the average temperature difference over the heating season are given by Formula (C.11):

$$H_{g;H;adj} = \frac{\sum_{mH} H_{g;an;m}}{6} \times \frac{\sum_{mH} \left(\theta_{int;m;H} - \theta_{e;m;H}\right)}{6 \cdot \left(\theta_{int;an} - \theta_{e;an}\right)} \tag{C.11}$$

where mH denotes the sum over October to March (Northern hemisphere), or April to September (Southern hemisphere).

Seasonal values adjusted to the average temperature difference over the cooling season are given by Formula (C.12):

$$H_{g;C;adj} = \frac{\sum_{mC} H_{g;an;m}}{6} \times \frac{\sum_{mC} \left(\theta_{int;m;C} - \theta_{e;m;C}\right)}{6 \cdot \left(\theta_{int;an} - \theta_{e;an}\right)} \tag{C.12}$$

where mC denotes the sum over April to September (Northern hemisphere) or October to March (Southern hemisphere).

NOTE 3 $H_{g;H;adj}$ and $H_{g;C;adj}$ are intended for calculation of the time constant of the building or conditioned zone.

C.8 Total heat transfer during heating season or cooling season

The total heat transfer via the ground is the integral of the heat flow rate, which can be represented by a sum of monthly values:

$$Q = \sum_{m=m_1}^{m_2} Q_m \tag{C.13}$$

$$Q_m = 86\,400 \times N_m \cdot \Phi_m \tag{C.14}$$

where

Q is the total heat transfer, in J;

Q_m is the heat transfer in month m, in J;

N_m is the number of days in month m;

Φ_m is the rate of heat transfer in month m, in W;

m_1 is the first month of the heating or cooling season;

m_2 is the last month of the heating or cooling season;

86 400 is the number of seconds in one day.

In the case of an average heat flow rate from Formula (C.4) or Formula (C.7):

$$Q = 86\,400 \times N \cdot \Phi \tag{C.15}$$

where N is the total number of days in the heating season.

Annex D
(normative)

Slab-on-ground with edge insulation

D.1 General

A slab-on-ground floor can have edge insulation, placed either horizontally or vertically along the perimeter of the floor. The formulae given in this annex are applicable when the width or depth of the edge insulation, D, is small compared to the width of the building.

Numerical methods may be used as an alternative. Where numerical calculations of linear thermal transmittance incorporate the effect of any edge insulation, calculations in accordance with this annex shall not be included in addition.

A template for defining any restrictions on use of the method in this annex is given in Table A.10, with an informative default choice provided in Table B.10.

The effect of edge insulation is treated as a linear thermal transmittance, $\Psi_{g,ed}$, which is obtained in accordance with D.2 for horizontal edge insulation, or in accordance with D.3 for vertical edge insulation. Low-density foundations, of thermal conductivity less than that of the soil, are treated as vertical edge insulation. $\Psi_{g,ed}$ has a negative value.

If the foundation detail has more than one piece of edge insulation (vertically or horizontally, internally or externally), calculate $\Psi_{g,ed}$ by the procedures below for each edge insulation separately, and use that giving the greatest reduction in heat loss.

NOTE 1 The formulae given in this annex provide good estimates of the effect of adding edge insulation to uninsulated floors. They underestimate the effect of adding additional edge insulation to an already insulated floor but can nevertheless be used the effect of the edge insulation will be at least that predicted.

Formulae (D.5) and (D.6) include the additional equivalent thickness resulting from the edge insulation, d', defined as:

$$d' = R' \lambda \tag{D.1}$$

where R' is the additional thermal resistance introduced by the edge insulation (or foundation), i.e. the difference between the thermal resistance of the edge insulation and that of the soil (or slab) it replaces:

$$R' = R_n - \frac{d_n}{\lambda} \tag{D.2}$$

where

R_n is the thermal resistance of the horizontal or vertical edge insulation (or foundation), in $m^2 \cdot K/W$;

d_n is the thickness of the edge insulation (or foundation), in m.

When $\Psi_{g,ed}$ is included in the calculation, Formula (1) is modified to:

$$H_g = (A \cdot U) + P \cdot (\Psi_{wf} + \Psi_{g;ed}) \quad (D.3)$$

For steady-state calculations, the effect of the edge insulation may be incorporated into the thermal transmittance of the floor using Formula (D.4).

$$U_{fg;sog} = U_{fg;sog;0} + \frac{2 \cdot \Psi_{g;ed}}{B} \quad (D.4)$$

where $U_{fg;sog;0}$ is the thermal transmittance of the floor without edge insulation; in which case, Formula (1) applies for calculation of the steady-state ground heat transfer coefficient.

NOTE 2 Any all-over insulation of the floor slab is included in the calculation of U_0.

NOTE 3 Both Ψ_g and $\Psi_{g;ed}$ are included in H_{pi} and H_{pe} (see Annex C).

D.2 Horizontal edge insulation

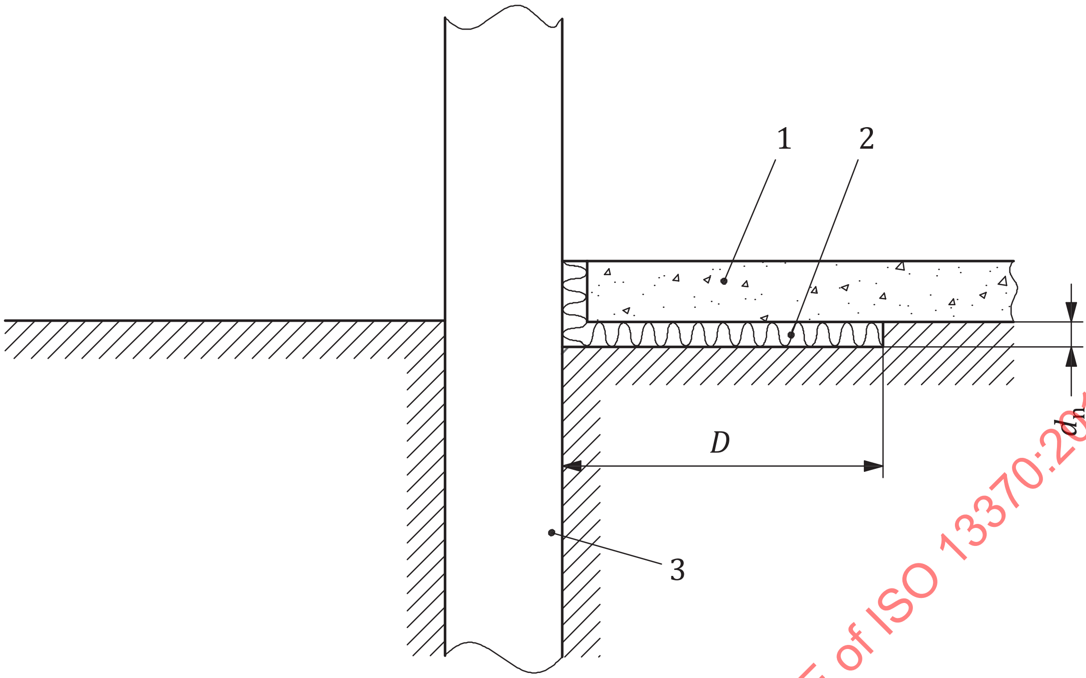
Formula (D.5) applies to insulation placed horizontally along the perimeter of the floor (see Figure D.1):

$$\Psi_{g;ed} = -\frac{\lambda}{\pi} \cdot \left[\ln\left(\frac{D}{d_f} + 1\right) - \ln\left(\frac{D}{d_f + d'} + 1\right) \right] \quad (D.5)$$

where

D is the width of horizontal edge insulation, in m;

d' is as defined in Formula (D.1).



Key

1 floor slab

2 horizontal edge insulation

3 foundation wall

d_n thickness of the edge insulation (or foundation)

D width of horizontal edge insulation

Figure D.1 — Schematic diagram of horizontal edge insulation

Figure D.1 shows edge insulation below the slab. Formula (D.5) also applies to horizontal edge insulation above the slab or external to the building.

D.3 Vertical edge insulation

Formula (D.6) applies to insulation placed vertically below ground along the perimeter of the floor (see Figure D.2) and to foundations of material of lower thermal conductivity than the ground (see Figure D.3):

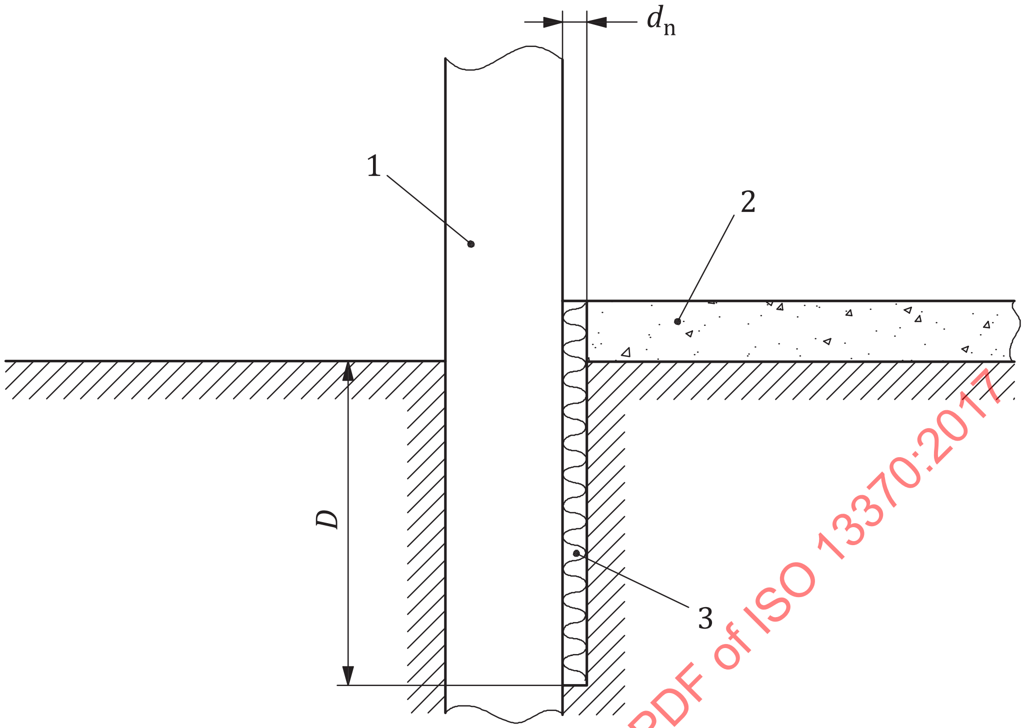
$$\Psi_{\mathrm{w;f}} = -\frac{\lambda}{\pi} \cdot \left[\ln\left(\frac{2 \cdot D}{d_{\mathrm{f}}} + 1 \right) - \ln\left(\frac{2 \cdot D}{d_{\mathrm{f}} + d'} + 1 \right) \right] \quad \text{(D.6)}$$

where

D is the depth of vertical edge insulation (or foundation) below ground level, in m;

d' is as defined in Formula (D.1).

Figure D.2 shows edge insulation inside the foundation wall. Formula (D.6) also applies to vertical edge insulation outside or within the foundation wall.



Key

1 foundation wall

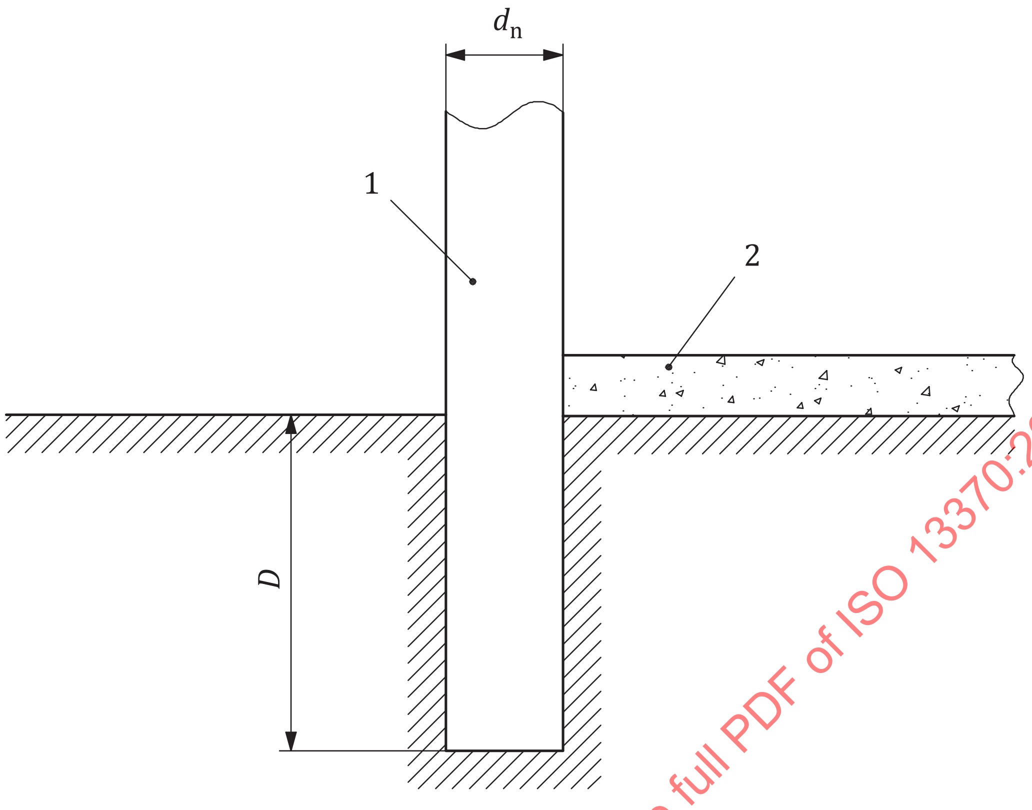
2 floor slab

3 vertical edge insulation

d_n thickness of the edge insulation (or foundation)

D depth of vertical edge insulation (or foundation) below ground level

Figure D.2 — Vertical edge insulation (insulation layer)



Key

1 low density foundation wall with $\lambda_n < \lambda$

2 floor slab

d_n thickness of the edge insulation (or foundation)

D depth of vertical edge insulation (or foundation) below ground level

Figure D.3 — Vertical edge insulation (low density foundation)

Annex E
(informative)

Heat flow rates for edge and central regions of a building

The formulae in this document give the total heat flow rate through the whole floor. When the heat flow rate is required for individual rooms of a building, in which some rooms have external walls and some do not, the heat flow through the floor may be divided into two parts, applicable respectively to rooms having external walls (the edge region) and rooms having no external walls (the central region). To obtain the total heat flow for each region, add the contribution due to the walls and other elements.

The steady-state heat flow rate is first calculated for the whole floor, Φ_t. This is then divided into heat flow rate for the edge region, Φ_e, and for the central region, Φ_m, as follows:

$$\Phi_e = \Phi_t \cdot \frac{A_e}{A_m \left(\dfrac{b + d_{f;tot}}{0,5 \times B + d_{f;tot}} \right) + A_e} \tag{E.1}$$

$$\Phi_m = \Phi_t - \Phi_e \tag{E.2}$$

$$q_e = \frac{\Phi_e}{A_e} \tag{E.3}$$

$$q_m = \frac{\Phi_m}{A_m} \tag{E.4}$$

where

q_e is the density of heat flow rate for rooms at the edge of the building;

q_m is the density of heat flow rate for rooms in the middle of the building;

A_e is the total floor area of rooms at the edge of the building;

A_m is the total floor area of rooms in the middle of the building;

b is the average width of rooms at the edge of the building, equal to A_e divided by the total exposed perimeter;

$d_{f;tot}$ is the total equivalent thickness, d_f, calculated according to Clause 7, applied to the floor of the whole building;

B is the characteristic dimension of the whole floor as defined in 6.7.1.

Periodic heat transfer due to annual variation in external temperature should be applied only to rooms at the edge of the building.

Annex F
(normative)

Application to dynamic calculation programmes

NOTE 1 The quantities in this sub-clause are also for use in the hourly calculation method of ISO 52016-1. See C.7 for input quantities for the monthly calculation method in ISO 52016-1.

This annex provides a method for treating heat transfers through the ground in connection with transient methods for the calculation of heat flows or temperatures in buildings, using a time interval of one hour or less.

The floor construction together with the ground is modelled as a single component, consisting of each layer in the floor construction plus 0,5 m depth of ground plus a virtual layer.

Table 9 provides different choices for the properties for the 0,5 m ground layer. A template for the choices is given in Table A.4, with an informative default choice provided in Table B.4.

In this annex, U is $U_{fg;sog}$, $U_{fg;sus}$, $U_{bg;eff}$ or U_{ub}, depending on floor type.

The virtual layer is included so that the annual average heat flow is correct. It has a thermal resistance R_{vi} and has negligible thermal capacity. R_{vi} is calculated from Formula (F.1):

$$R_{vi} = \frac{1}{U} - R_{si} - R_f - R_g \tag{F.1}$$

where

U is the steady-state thermal transmittance of the floor including the effect of the ground, calculated by the methods in this document or by a numerical method using the boundary conditions and assumptions applicable to calculation of U by this document;

R_{si} is the internal surface resistance of the floor;

R_f is the total thermal resistance of all layers in the floor construction;

R_g is the thermal resistance of 0,5 m of ground; $R_g = 0{,}5 / \lambda_g$ (see Table 9).

For the purposes of the thermal model, the virtual layer can be assigned a thickness of 0,1 m so that its thermal conductivity is $0{,}1/R_{vi}$. Its density and specific heat capacity should be zero or very small values (1 kg/m^3 and 1 J/(kg·K), respectively).

The boundary condition at the bottom of the virtual layer is a virtual temperature, θ_{vi}.

θ_{vi} can be assigned for each month of the year according to

$$\theta_{vi,m} = \theta_{int,m} - \frac{\Phi_m - P \cdot \Psi_{wf} \cdot \left(\bar{\theta}_{int} - \bar{\theta}_e\right)}{A \cdot U} \tag{F.2}$$

where Φ_m is calculated in accordance with Formula (C.4) and the other inputs to the formula are explained under Formula (1) and/or Formula (C.3).

NOTE As the formula for the virtual temperature shows, any edge-related heat transfer is explicitly subtracted from the monthly heat flow rate. In dynamic calculations, the edge-related heat transfer is a linear heat flow element without inertia, like all other linear thermal bridge elements.

