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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

ISO 13370:1998(E)

Foreword

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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.

International Standard ISO 13370 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 163, *Thermal insulation*, Subcommittee SC 2, *Calculation methods*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Annexes A to F form an integral part of this International Standard. Annexes G to L are for information only.

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Contents

Foreword

The text of EN ISO 13370:1998 has been prepared by Technical Committee CEN/TC 89 "Thermal performance of buildings and building components", the secretariat of which is held by SIS, in collaboration with Technical Committee ISO/TC 163 "Thermal insulation".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 1999, and conflicting national standards shall be withdrawn at the latest by April 1999.

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

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

Introduction

EN ISO 6946 gives the method of calculation of the thermal transmittance of building elements in contact with the external air; this standard deals with elements in thermal contact with the ground. The division between these two 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 prEN 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 standard, simplified procedures are provided which take account of the 3-dimensional nature of the heat flow and which are suitable for the evaluation of heat transfer coefficients and heat flow rates in most cases.

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.

A detailed assessment of floor losses is obtained from, in addition to the steady-state part, 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. Methods of obtaining these periodic coefficients are also given in this standard, and their application to the calculation of heat flow rates is described in annex B.

Worked examples illustrating the use of the methods in this standard are given in annex L.

1 Scope

This standard gives 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

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

It 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; this standard does not apply to shorter periods of time.

2 Normative references

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

EN ISO 6946	Building components and building elements - Thermal resistance and thermal transmittance - Calculation method (ISO 6946:1996)
EN ISO 7345	Thermal insulation - Physical quantities and definitions (ISO 7345:1987)
EN ISO 10211-1	Thermal bridges - Calculation of heat flows and surface temperatures - Part 1: General calculation methods (ISO 10211-1:1995)
prEN ISO 10211-2	Thermal bridges - Calculation of heat flows and surface temperatures - Part 2: Linear thermal bridges (ISO/DIS 10211-2:1995)
ISO 10456	Building materials and products - Procedures for determining declared and design thermal values

3 Definitions, symbols and units

3.1 Definitions

For the purposes of this standard the definitions in EN ISO 7345 apply, together with the following.

3.1.1 slab on ground: Floor construction directly on the ground over its whole area.

3.1.2 suspended floor: Floor construction in which the floor is held off the ground, resulting in an air void between the floor and the ground.

NOTE - This air void, also called underfloor space or crawl space, may be ventilated or unventilated, and does not form part of the habitable space.

3.1.3 basement: Usable part of a building that is situated partly or entirely below ground level.

NOTE - This space may be heated or unheated.

3.1.4 equivalent thickness (of a thermal resistance): Thickness of ground (having the thermal conductivity of the actual ground) which has the same thermal resistance.

3.1.5 steady-state thermal coupling coefficient: Steady-state heat flow divided by temperature difference between internal and external environments.

3.1.6 internal periodic thermal coupling coefficient: Amplitude of periodic heat flow divided by amplitude of internal temperature variation over an annual cycle.

3.1.7 external periodic thermal coupling coefficient: Amplitude of periodic heat flow divided by amplitude of external temperature over an annual cycle.

3.1.8 characteristic dimension of floor: Area of floor divided by half the perimeter of floor.

3.1.9 phase difference: Period of time between the maximum or minimum of a cyclic temperature and the consequential maximum or minimum heat flow rate.

3.2 Symbols and units

The following is a list of the principal symbols used. Other symbols are defined where they are used within the text.

Symbol	Quantity	Unit
A	area of floor	m²
B'	characteristic dimension of floor	m
D	width or depth of edge insulation	m
L_s	steady-state thermal coupling coefficient	W/K
L_{pi}	internal periodic thermal coupling coefficient	W/K
L_{pe}	external periodic thermal coupling coefficient	W/K

Symbol	Quantity	Unit
P	exposed perimeter of floor	m
Q	quantity of heat	J
R	thermal resistance	$m^2 \cdot K/W$
R_f	thermal resistance of floor construction	$m^2 \cdot K/W$
R_{ins}	thermal resistance of insulation	$m^2 \cdot K/W$
R_{si}	internal surface resistance	$m^2 \cdot K/W$
R_{se}	external surface resistance	$m^2 \cdot K/W$
T	temperature	K or °C
U	thermal transmittance between internal and external environments	$W/(m^2 \cdot K)$
U_o	basic thermal transmittance of slab-on-ground floor	$W/(m^2 \cdot K)$
U_{bf}	thermal transmittance of basement floor	$W/(m^2 \cdot K)$
U_{bw}	thermal transmittance of basement walls	$W/(m^2 \cdot K)$
U'	effective thermal tranmittance for whole basement	$W/(m^2 \cdot K)$
d_t	total equivalent thickness - floor	m
d_w	total equivalent thickness - basement wall	m
c	specific heat capacity of unfrozen ground	$J/(kg \cdot K)$
d'	additional equivalent thickness due to edge insulation	m
h	height of floor surface above outside ground level	m
w	thickness of external walls	m
z	depth of basement floor below ground level	m
δ	periodic penetration depth	m
λ	thermal conductivity of unfrozen ground	$W/(m \cdot K)$
λ_n	thermal conductivity of insulation	$W/(m \cdot K)$
ρ	density of unfrozen ground	kg/m^3
Φ	heat flow rate	W
Ψ_g	linear thermal transmittance associated with wall/floor junction	$W/(m \cdot K)$
$\Delta\Psi$	correction term for edge insulation of floor slab	$W/(m \cdot K)$

4 Thermal properties

4.1 Thermal properties of the ground

The thermal properties of the ground may be specified in national regulations or other documents, and such values may be used where appropriate. In other cases:

a) if known, use values for the actual location, averaged over a depth equal to the width of the building and allowing for the normal moisture content;

b) otherwise, if the soil type is known or specified, use the values in table 1;

c) otherwise use λ = 2,0 W/(m·K) and ρc = 2,0 x 10^6 J/(m³·K).

Table 1 - Thermal properties of the ground

Category	Description	Thermal conductivity λ (W/(m·K))	Heat capacity per volume ρc (J/(m³·K))
1	clay or silt	1,5	3,0 x 10^6
2	sand or gravel	2,0	2,0 x 10^6
3	homogeneous rock	3,5	2,0 x 10^6

NOTE - Annex G gives information about the range of values of ground properties.

4.2 Thermal properties of building materials

For the thermal resistance of any building product use the appropriate design value as defined in ISO 10456. The thermal resistance of products used below ground level should reflect the moisture conditions of the application.

If thermal conductivity is quoted, obtain the thermal resistance as the thickness divided by thermal conductivity.

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

4.3 Surface resistances

Use the following values:

- internal, downwards heat flow: R_{si} = 0,17 m²·K/W
- internal, horizontal heat flow: R_{si} = 0,13 m²·K/W
- internal, upwards heat flow: R_{si} = 0,10 m²·K/W
- external, all cases: R_{se} = 0,04 m²·K/W

NOTE - These values are taken from ISO 6946.

R_{si} for downwards heat flow applies both at the top and the bottom of an underfloor space. R_{si} for upwards heat flow applies to floors with an embedded heating system and to cold stores.

5 Internal temperature and climatic data

5.1 Internal temperature.

If there are different temperatures in different rooms or spaces immediately above the floor, a spatial average should be used. 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 standard requires:

a) annual mean internal temperature;

b) if variations in internal temperature are 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.

5.2 Climatic data

To calculate heat flow rates this standard requires:

a) annual mean external air temperature;

b) if variations in external temperature are 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;

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

If the ground surface temperature is known or can be estimated, 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 longwave radiation to clear skies. In that case R_{se} should be excluded from all formulae.

6 Thermal transmittance and heat flow rate

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 clauses 8 to 12 for the various types of floor and basement: a summary of the relevant equations is provided in table 2.

If the transmission heat loss coefficient for the ground is required, take this as equal to the steady-state thermal coupling coefficient, L_s.

Table 2 - Selection of equations

Floor type:	For all floor types obtain B' using equation (1)	
Slab-on-ground	Calculate d_t using (2), and U_o using (3) or (4)	No edge insulation: $U = U_o$
		Edge insulation: $U = U_o + 2\,\Delta\Psi/B'$ Horizontal edge insulation: d' from (8) and $\Delta\Psi$ from (10) Vertical edge insulation: d' from (8) and $\Delta\Psi$ from (11)
Suspended	Calculate d_g using (14), U_g using (15), U_x using (16) and finally U using (13)	
Basement	Basement floor: Calculate d_t using (18) Calculate U_{bf} using (19) or (20)	Heated basement: Calculate U' using (23)
	Basement walls: Calculate d_w using (21) and U_{bw} using (22)	Unheated basement : Calculate U using (25)

6.2 Thermal bridges at edge of floor

The formulae in this standard 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).

Typical values of Ψ for slab-on-ground floors are given in table 3. This table may be extended on a national basis to include specific wall/floor details, and for a particular dimension system, provided that these values have been obtained in accordance with annex A. The linear thermal transmittance term associated with basements is small and may be neglected.

NOTE: The linear thermal transmittance depends on the system being used for defining building dimensions: see prEN ISO 13789 *Thermal performance of buildings - Transmission heat loss coefficient - Calculation Method (ISO/DIS 13789:1997)*

Table 3 - Values of linear thermal transmittance for wall/floor junctions for slab-on-ground and suspended floors

Insulation arrangement	Linear thermal transmittance Ψ W/(m·K)
Uninsulated floor, or floor in which floor insulation connects directly to wall insulation	0,0
Wall insulation not directly connected to floor insulation, but overlapped with it by at least 200 mm	0,1
Wall insulation not connected to floor insulation	0,2

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.

The thermal transmittance of elements above the separating plane should be assessed according to EN ISO 6946.

6.3 Calculation of heat flow rate

Heat transfer via the ground can be calculated on an annual basis using thermal transmittances only, or on a seasonal or monthly basis using additional periodic coefficients that take account of the thermal inertia of the ground. The relevant equations are given in annex B, and formulae for the periodic coefficients in annex C.

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.

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

NOTE - Illustrative values of G_w are given in annex H.

6.5 Special cases

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

– Heat flow rates for individual rooms : annex D

– Application to dynamic simulation programs: annex E

NOTE: This standard can also be used for slab-on-ground floors with an embedded heating system (see annex J) and for cold stores (see annex K).

7 Parameters used in the calculations

7.1 Characteristic dimension of floor

To allow for the 3-dimensional nature of heat flow within the ground, the formulae in this standard are expressed in terms of the "characteristic dimension" of the floor, *B'*, defined as the area of the floor divided by half the perimeter:

$$B' = \frac{A}{\frac{1}{2} P} \qquad (1)$$

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, for example 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, not including the walls 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 standard, *P* is the exposed perimeter of the floor: the total length of external wall dividing the heated building from the external environment or from an unheated space outside the insulated fabric. Thus:

– 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 (for example 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;

– 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).

7.2 Equivalent thickness

The concept of "equivalent thickness" is introduced to simplify the expression of the thermal coupling coefficients.

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

– d_t is the equivalent thickness for floors;
– d_w is the equivalent thickness for walls of basements below ground level.

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

8 Slab-on-ground floor: uninsulated or with all-over insulation

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 may be:

– uninsulated, or

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

NOTE - Both uninsulated and evenly insulated slabs may have horizontal and/or vertical edge insulation: these are treated in clause 9.

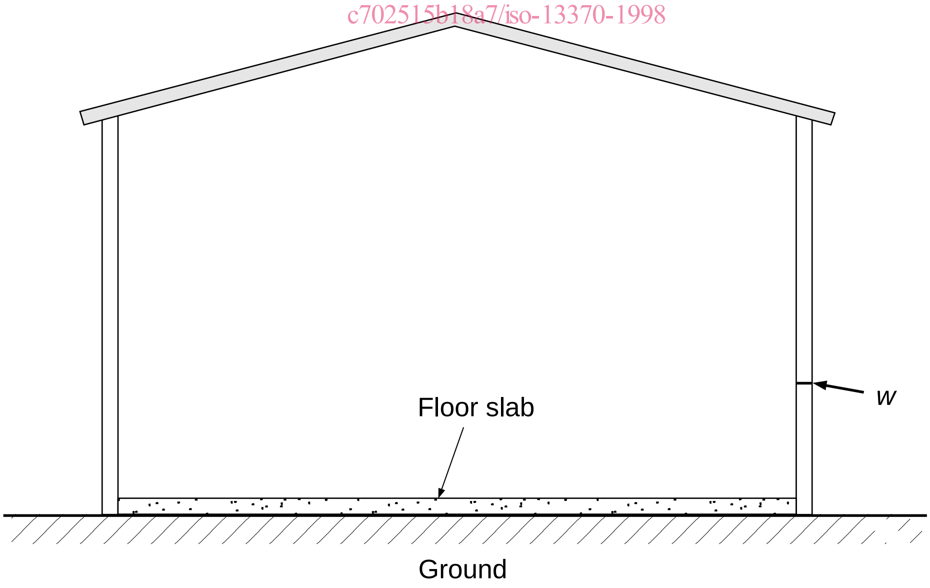

Figure 1 - Schematic diagram of slab-on-ground floor

The thermal transmittance depends on the characteristic dimension of the floor B' (see 7.1 and equation (1)), and the total equivalent thickness d_t (see 7.2) defined as follows:

$$d_t = w + \lambda\,(R_{si} + R_f + R_{se}) \quad (2)$$

where the symbols are defined in 3.2.

w is the full thickness of the walls, including all layers. R_f includes the thermal resistance of any all-over insulation layers above, below or within the floor slab, and that of any floor covering. The thermal resistance of dense concrete slabs and thin floor coverings may be neglected. Hardcore below the slab is assumed to have the same thermal conductivity as the ground and its thermal resistance should not be included.

To calculate the basic thermal transmittance, U_o, use either (3) or (4), depending on the thermal insulation of the floor.

If $d_t < B'$ (uninsulated and moderately insulated floors):

$$U_o = \frac{2\lambda}{\pi B' + d_t} \ln\left(\frac{\pi B'}{d_t} + 1\right) \quad (3)$$

If $d_t \geq B'$ (well-insulated floors):

$$U_o = \frac{\lambda}{0{,}457 B' + d_t} \quad (4)$$

For floors without edge insulation

$$U = U_o \quad (5)$$

and with edge insulation

$$U = U_o + 2\,\Delta\Psi / B' \quad (6)$$

The steady-state thermal coupling coefficient is:

$$L_s = A\,U_o + P\,\Delta\Psi \quad (7)$$

9 Slab-on-ground with edge insulation

9.1 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 clause 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 (see annex A).

First obtain the basic thermal transmittance U_0 according to clause 8 ignoring the edge insulation (but including any all-over insulation). Then obtain the correction term $\Delta\Psi$ according to 9.2 for horizontal edge insulation, or according to 9.3 for vertical edge insulation. The thermal transmittance of the floor is given by equation (6) and the steady-state thermal coupling coefficient by equation (7).

Low-density foundations, of thermal conductivity less than that of the soil, are treated as vertical edge insulation.

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

> NOTE - The formulae given below 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.

The equations (10) and (11) include the additional equivalent thickness resulting from the edge insulation, d':

$$d' = R' \lambda \tag{8}$$

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

$$R' = R_n - d_n/\lambda \tag{9}$$

where:

- R_n is the thermal resistance of the horizontal or vertical edge insulation (or foundation), in m²·K/W;
- d_n is the thickness of the edge insulation (or foundation), in m.