

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

The European Standard EN ISO 13370:1998 has the status of a
British Standard

ICS 91.120.10

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN ISO title page, pages 2 to 41 and a back cover. This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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English version

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Heat transfer via the ground —
Calculation methods

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Wärmetechnisches Verhalten von Gebäuden —
Wärmeübertragung über das Erdreich —
Berechnungsverfahren
(ISO 13370:1998)

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Central Secretariat: rue de Stassart 36, B-1050 Brussels

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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of an identical text or by endorsement, at the latest by April 1999, and conflicting national standards shall be withdrawn at the latest by July 1999.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.

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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	m^2
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
P	exposed perimeter of floor	m
Q	quantity of heat	J
R	thermal resistance	$\text{m}^2 \text{ K/W}$
R_f	thermal resistance of floor construction	$\text{m}^2 \text{ K/W}$
R_{ins}	thermal resistance of insulation	$\text{m}^2 \text{ K/W}$
R_{si}	internal surface resistance	$\text{m}^2 \text{ K/W}$
R_{se}	external surface resistance	$\text{m}^2 \text{ K/W}$
T	temperature	K or $^{\circ}\text{C}$
U	thermal transmittance between internal and external environments	$\text{W}/(\text{m}^2 \text{ K})$
U_o	basic thermal transmittance of slab-on-ground floor	$\text{W}/(\text{m}^2 \text{ K})$
U_{bf}	thermal transmittance of basement floor	$\text{W}/(\text{m}^2 \text{ K})$
U_{bw}	thermal transmittance of basement walls	$\text{W}/(\text{m}^2 \text{ K})$
U'	effective thermal transmittance for whole basement	$\text{W}/(\text{m}^2 \text{ K})$
d_t	total equivalent thickness — floor	m
d_w	total equivalent thickness — basement wall	m
c	specific heat capacity of unfrozen ground	$\text{J}/(\text{kg K})$
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	$\text{W}/(\text{m K})$
λ_n	thermal conductivity of insulation	$\text{W}/(\text{m K})$
ρ	density of unfrozen ground	kg/m^3
Φ	heat flow rate	W
Ψ_g	linear thermal transmittance associated with wall/floor junction	$\text{W}/(\text{m K})$
$\Delta\Psi$	correction term for edge insulation of floor slab	$\text{W}/(\text{m K})$

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 $\lambda = 2,0 \text{ W/(m K)}$ and $\rho c = 2,0 \times 10^6 \text{ J/(m}^3 \text{ K)}$.

Table 1 — Thermal properties of the ground

Category	Description	Thermal conductivity $\lambda \text{ [W/(m K)]}$	Heat capacity per volume $\rho c \text{ [J/(m}^3 \text{ K)]}$
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	$2,0 \times 10^6$

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: $R_{si} = 0,17 \text{ m}^2 \text{ K/W}$
- internal, horizontal heat flow: $R_{si} = 0,13 \text{ m}^2 \text{ K/W}$
- internal, upwards heat flow: $R_{si} = 0,10 \text{ m}^2 \text{ K/W}$
- external, all cases: $R_{se} = 0,04 \text{ m}^2 \text{ K/W}$

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.

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) Basement walls: Calculate d_w using (21) and U_{bw} using (22)	Heated basement: Calculate U' using (23)
		Unheated basement: Calculate U using (25)

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_g .

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:

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