INTERNATIONAL STANDARD

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Building components and building elements — Thermal resistance and thermal transmittance — Calculation method

Composants et parois de bâtiments — Résistance thermique et coefficient de transmission thermique — Méthode de calcul

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Contents

Page

Foreword

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

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

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

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

ISO 6946 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods*.

This second edition cancels and replaces the first edition (ISO 6946:1996), which has been technically revised. It also incorporates the Amendment ISO 6946:1996/Amd.1:2003.

The following changes have been made to the first edition:

— information on the calculation of heat flow rates has been transferred from the Introduction to the note in Clause 4;

— 5.3.3 provides an amended basis for slightly ventilated air layers;

— 5.4.2 provides clarification of the applicability of Table 3;

— 5.4.3 has been completely revised;

— 6.2.1 provides a new text to allow calculation of a component that is part of a complete element; it also clarifies exceptions and the limit of applicability;

— Annex B provides additional data for other temperature differences across cavities; it also provides a correction to the formula for radiation transfer in divided airspaces;

— Annex C contains an additional shape;

— D.2 has been completely rewritten to clarify the intentions, the former Annex E having been deleted (national annexes can be attached to this International Standard giving examples in accordance with local building traditions);

— D.3 provides a revised procedure for mechanical fasteners, including recessed fasteners;

— D.4 does not apply in cooling situations.

Introduction

This International Standard 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.

Building components and building elements — Thermal resistance and thermal transmittance — Calculation method

1 Scope

This International Standard provides the method of calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units, curtain walling, components which involve heat transfer to the ground, and components through which air is designed to permeate.

The calculation method is based on the appropriate design thermal conductivities or design thermal resistances of the materials and products for the application concerned.

The method applies to components and elements consisting of thermally homogeneous layers (which can include air layers).

This International Standard also provides an approximate method that can be used for elements containing inhomogeneous layers, including the effect of metal fasteners, by means of a correction term given in Annex D. Other cases where insulation is bridged by metal are outside the scope of this International Standard.

2 Normative references

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

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

ISO 10456, *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values*

ISO 13789, *Thermal performance of buildings — Transmission and ventilation heat transfer coefficients — Calculation method*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345 and ISO 10456 and the following apply.

3.1.1
building element
major part of a building such as a wall, floor or roof

3.1.2
building component
building element or a part of it

NOTE In this International Standard, the word "component" is used to indicate both element and component.

3.1.3
thermally homogeneous layer
layer of constant thickness having thermal properties which may be regarded as being uniform

3.2 Symbols and units

Symbol	Quantity	Unit
A	area	m^2
d	thickness	m
h	surface heat transfer coefficient	$W/(m^2 \cdot K)$
R	design thermal resistance (surface to surface)	$m^2 \cdot K/W$
R_g	thermal resistance of airspace	$m^2 \cdot K/W$
R_{se}	external surface resistance	$m^2 \cdot K/W$
R_{si}	internal surface resistance	$m^2 \cdot K/W$
R_T	total thermal resistance (environment to environment)	$m^2 \cdot K/W$
R'_T	upper limit of total thermal resistance	$m^2 \cdot K/W$
R''_T	lower limit of total thermal resistance	$m^2 \cdot K/W$
R_u	thermal resistance of unheated space	$m^2 \cdot K/W$
U	thermal transmittance	$W/(m^2 \cdot K)$
λ	design thermal conductivity	$W/(m \cdot K)$

4 Principles

The principle of the calculation method is as follows:

— to obtain the thermal resistance of each thermally homogeneous part of the component;

— to combine these individual resistances so as to obtain the total thermal resistance of the component, including (where appropriate) the effect of surface resistances.

Thermal resistances of individual parts are obtained in accordance with 5.1.

The values of surface resistance given in 5.2 are appropriate in most cases. Annex A gives detailed procedures for low emissivity surfaces, specific external wind speeds and non-planar surfaces.

Air layers may be regarded as thermally homogeneous for the purposes of this International Standard. Values of the thermal resistance of large air layers with high emissivity surfaces are given in 5.3. Annex B provides procedures for other cases.

The resistances of the layers are combined as follows:

a) for components consisting of thermally homogeneous layers, obtain the total thermal resistance in accordance with 6.1 and the thermal transmittance in accordance with Clause 7;

b) for components having one or more thermally inhomogeneous layers, obtain the total thermal resistance in accordance with 6.2 and the thermal transmittance in accordance with Clause 7;

c) for components containing a tapered layer, obtain the thermal transmittance and/or the total thermal resistance in accordance with Annex C.

Finally, corrections are applied to the thermal transmittance, if appropriate, in accordance with Annex D, in order to allow for the effects of air voids in insulation, mechanical fasteners penetrating an insulation layer and precipitation on inverted roofs.

The thermal transmittance calculated in this way applies between the environments on either side of the component concerned, e.g. internal and external environments, two internal environments in the case of an internal partition, an internal environment and an unheated space. Simplified procedures are given in 5.4 for treating an unheated space as a thermal resistance.

NOTE Calculation of heat flow rates are commonly undertaken using operative temperature (usually approximated to the arithmetic mean of air temperature and mean radiant temperature) to represent the environment inside buildings, and air temperature to represent the external environment. Other definitions of the temperature of an environment are also used when appropriate to the purpose of the calculation. See also Annex A.

5 Thermal resistances

5.1 Thermal resistance of homogeneous layers

Design thermal values can be given as either design thermal conductivity or design thermal resistance. If thermal conductivity is given, obtain the thermal resistance of the layer from

$$R = \frac{d}{\lambda} \tag{1}$$

where

d is the thickness of the material layer in the component;

λ is the design thermal conductivity of the material, either calculated in accordance with ISO 10456 or obtained from tabulated values.

NOTE The thickness, d, can be different from the nominal thickness (e.g. when a compressible product is installed in a compressed state, d is less than the nominal thickness). If relevant, it is advisable that d also make appropriate allowance for thickness tolerances (e.g. when they are negative).

Thermal resistance values used in intermediate calculations shall be calculated to at least three decimal places.

5.2 Surface resistances

Use the values in Table 1 for plane surfaces in the absence of specific information on the boundary conditions. The values under “horizontal” apply to heat flow directions ± 30° from the horizontal plane. For non-planar surfaces or for specific boundary conditions, use the procedures in Annex A.

Table 1 — Conventional surface resistances

Surface resistance m²·K/W	Direction of heat flow		
	Upwards	Horizontal	Downwards
R_{si}	0,10	0,13	0,17
R_{se}	0,04	0,04	0,04

NOTE 1 The values given are design values. For the purposes of declaration of the thermal transmittance of components and other cases where values independent of heat flow direction are required, or when the heat flow direction is liable to vary, it is advisable that the values for horizontal heat flow be used.

NOTE 2 The surface resistances apply to surfaces in contact with air. No surface resistance applies to surfaces in contact with another material.

5.3 Thermal resistance of air layers

5.3.1 Applicability

The values given in 5.3.1 to 5.3.3 apply to an air layer which

— is bounded by two faces that are effectively parallel and perpendicular to the direction of heat flow and that have emissivities not less than 0,8,

— has a thickness (in the direction of heat flow) of less than 0,1 times each one of the other two dimensions, and not greater than 0,3 m,

— has no air interchange with the internal environment.

If the above conditions do not apply, use the procedures in Annex B.

NOTE Most building materials have an emissivity greater than 0,8.

A single thermal transmittance should not be calculated for components containing air layers thicker than 0,3 m. Instead, heat flows should be calculated by performing a heat balance (see ISO 13789).

5.3.2 Unventilated air layer

An unventilated air layer is one in which there is no express provision for air flow through it. Design values of thermal resistance are given in Table 2. The values under “horizontal” apply to heat flow directions ± 30° from the horizontal plane.

An air layer having no insulation between it and the external environment, but with small openings to the external environment, shall also be considered as an unventilated air layer if these openings are not arranged so as to permit air flow through the layer and they do not exceed

— 500 mm² per metre of length (in the horizontal direction) for vertical air layers,

— 500 mm² per square metre of surface area for horizontal air layers.

NOTE Drain openings (weep holes) in the form of open vertical joints in the outer leaf of a masonry cavity wall usually conform with the above criteria and so are not regarded as ventilation openings.

Table 2 — Thermal resistance of unventilated air layers with high emissivity surfaces

Thickness of air layer	Thermal resistance $m^2 \cdot K/W$		
	Direction of heat flow		
mm	Upwards	Horizontal	Downwards
0	0,00	0,00	0,00
5	0,11	0,11	0,11
7	0,13	0,13	0,13
10	0,15	0,15	0,15
15	0,16	0,17	0,17
25	0,16	0,18	0,19
50	0,16	0,18	0,21
100	0,16	0,18	0,22
300	0,16	0,18	0,23

NOTE Intermediate values may be obtained by linear interpolation.

5.3.3 Slightly ventilated air layer

A slightly ventilated air layer is one in which there is provision for limited air flow through it from the external environment by openings of area, A_v, within the following ranges:

— $>$ 500 mm^2 but $<$ 1 500 mm^2 per metre of length (in the horizontal direction) for vertical air layers;

— $>$ 500 mm^2 but $<$ 1 500 mm^2 per square metre of surface area for horizontal air layers.

The effect of ventilation depends on the size and distribution of the ventilation openings. As an approximation, the total thermal resistance of a component with a slightly ventilated air layer may be calculated as

$$R_T = \frac{1500 - A_v}{1000} R_{T,u} + \frac{A_v - 500}{1000} R_{T,v} \quad (2)$$

where

$R_{T,u}$ is the total thermal resistance with an unventilated air layer in accordance with 5.3.2;

$R_{T,v}$ is the total thermal resistance with a well-ventilated air layer in accordance with 5.3.4.

5.3.4 Well-ventilated air layer

A well-ventilated air layer is one for which the openings between the air layer and the external environment are equal to or exceed

— 1 500 mm^2 per metre of length (in the horizontal direction) for vertical air layers,

— 1 500 mm^2 per square of metre of surface area for horizontal air layers.

The total thermal resistance of a building component containing a well-ventilated air layer shall be obtained by disregarding the thermal resistance of the air layer and all other layers between the air layer and external environment, and including an external surface resistance corresponding to still air (see Annex A). Alternatively, the corresponding value of R_{si} from Table 1 may be used.

5.4 Thermal resistance of unheated spaces

5.4.1 General

When the external envelope of the unheated space is not insulated, the simplified procedures in 5.4.2 and 5.4.3, treating the unheated space as a thermal resistance, may be applied.

NOTE 1 ISO 13789 gives general and more precise procedures for the calculation of heat transfer from a building to the external environment via unheated spaces, which it is advisable to use when a more accurate result is required. For crawl spaces below suspended floors, see ISO 13370.

NOTE 2 The thermal resistances given in 5.4.2 and 5.4.3 are suitable for heat flow calculations, but not for calculations concerned with the hygrothermal conditions in the unheated space.

5.4.2 Roof spaces

For a roof structure consisting of a flat, insulated ceiling and a pitched roof, the roof space may be regarded as if it were a thermally homogeneous layer with thermal resistance as given in Table 3.

Table 3 — Thermal resistance of roof spaces

	Characteristics of roof	R_u m²·K/W
1	Tiled roof with no felt, boards or similar	0,06
2	Sheeted roof, or tiled roof with felt or boards or similar under the tiles	0,2
3	As 2 (above) but with aluminium cladding or other low emissivity surface at underside of roof	0,3
4	Roof lined with boards and felt	0,3
NOTE The values in this table include the thermal resistance of the ventilated space and the thermal resistance of the (pitched) roof construction. They do not include the external surface resistance, R_{se}.		

The data in Table 3 apply to naturally ventilated roof spaces above heated buildings. If mechanically ventilated, use the detailed procedure in ISO 13789, treating the roof space as an unheated space with a specified ventilation rate.

5.4.3 Other spaces

When a building has an unheated space adjacent to it, the thermal transmittance between the internal and external environments can be obtained by treating the unheated space together with its external construction components as if it were an additional homogeneous layer with thermal resistance, R_u. When all elements between the internal environment and the unheated space have the same thermal transmittance, R_u is given by

$$R_u = \frac{A_i}{\sum_k (A_{e,k}\ U_{e,k}) + 0{,}33 \times nV} \qquad (3)$$

where

A_i is the total area of all elements between the internal environment and the unheated space, in m²;

$A_{e,k}$ is the area of element k between the unheated space and the external environment, in m²;

