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

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

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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 6946 was prepared by the 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 6946:2007), 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.

This corrected version of ISO 6946:2017 incorporates the following corrections:

Formula (11): in the definition of A_{ve}, m^2 was changed to mm^2;

Formula (F.5): d_1 was replaced by d_0.

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)[1] 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.

This document provides calculation methods for the thermal transmittance of walls and roofs

— to allow comparisons between different constructions,

— to help in judging compliance with regulations, and

— to provide input data for calculation of annual energy use for heating or cooling buildings.

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 Clause 2 and 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									
Sub module	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 6946	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									

[a] The shaded modules are not applicable.

Table 1 *(continued)*

	Overarching		Building (as such)		Technical Building Systems									
Sub module	**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**
8	Building zoning		Solar heat gains		Generation and control									
9	Calculated energy performance		Building dynamics (thermal mass)		Load dispatching and operating conditions									
10	Measured energy performance		Measured energy performance		Measured energy performance									
11	Inspection		Inspection		Inspection									
12	Ways to express indoor comfort				BMS									
13	External environment conditions													
14	Economic calculation													

[a] The shaded modules are not applicable.

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

1 Scope

This document 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 document 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 F. Other cases where insulation is bridged by metal are outside the scope of this document.

NOTE 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 the 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 7345, *Thermal insulation — Physical quantities and definitions*

ISO 10211, *Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations*

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*

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, 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
building element
major part of a building

EXAMPLE Wall, floor or roof.

3.2
building component
building element or a part of it

Note 1 to entry: In this document, the word "component" is used to indicate both element and component.

3.3
design thermal value
design thermal conductivity or design thermal resistance

Note 1 to entry: The design value includes possible degrading effects from, for example, ageing, moisture and/or convection. In contrast to the declared value which is the expected value of a thermal property of a building material or product assessed from measured data at reference conditions of temperature and humidity, see ISO 10456.

3.4
design thermal conductivity
value of thermal conductivity of a building material or product under specific external and internal conditions which can be considered as typical of the performance of that material or product when incorporated in a building component

3.5
design thermal resistance
value of thermal resistance of a building product under specific external and internal conditions which can be considered as typical of the performance of that product when incorporated in a building component

3.6
EPB standard
standard that complies with the requirements given in ISO 52000-1, CEN/TS 16628[3] and CEN/TS 16629[4]

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]

3.7
thermally homogeneous layer
layer of constant thickness having thermal properties which may be regarded as being uniform

4 Symbols and subscripts

4.1 Symbols

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

Symbol	Quantity	Unit
A	area	m^2
d	thickness	m
h	surface coefficient of heat transfer	$W/(m^2 \cdot K)$
n	ventilation rate	1/h
R	thermal resistance	$m^2 \cdot K/W$
U	thermal transmittance	$W/(m^2 \cdot K)$
V	volume	m^3
λ	design thermal conductivity	$W/(m \cdot K)$

4.2 Subscripts

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

Subscript	Identification
a	air
c	component
eq	equivalent
e	external
f	mechanical fasteners
g	air voids
nve	not ventilated
op	opaque
r	inverted roofs
s	surface
si	internal surface
se	external surface
tot	total
tot;upper	upper limit of total value
tot;lower	lower limit of total value
u	unheated
ve	ventilated, ventilation

5 Description of the method

5.1 Output

The output of this document is the thermal resistance and thermal transmittance of a building component or building element. These quantities are calculated as a function of the thermal properties, composition and geometry of the element and the boundary conditions.

5.2 General description

There are two methods for calculating the thermal transmittance of a building component, as set out in 5.3 and 5.4.

In both cases, the thermal resistance is calculated from the thermal transmittance and the applicable surface resistances according to 6.6.

5.3 Detailed calculation method

The detailed calculation method is a numerical simulation carried out on the whole building element or on a representative part of it. The modelling rules shall be in accordance with those in ISO 10211. This method is valid for any building component.

5.4 Simplified calculation method

The simplified calculation method is described in Clause 6. It is valid for components consisting of thermally homogenous or inhomogeneous layers and which may contain air layers up to 0,3 m thick and metal fasteners, and is subject to the limitations in 6.7.2.1.

6 Calculation of thermal transmittance and thermal resistance

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 elements or components with horizontal heat flow	U	W/(m²·K)	M 2–5	≥0	No
thermal transmittance of elements or components with upwards heat flow	U	W/(m²·K)	M2–5	≥0	No
thermal transmittance of elements or components with downwards heat flow	U	W/(m²·K)	M2–5	≥0	No
thermal resistance of opaque component	$Rc;op$	m²·K/W	M2–5	≥0	No

6.2 Calculation time intervals

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.

6.3 Input data

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

Table 3 — Identifiers for geometric characteristics

Name	Symbol	Unit	Value	Range	Origin	Varying
area	A	m²	—	>0	—	No
thickness of material layer	d	m	—	>0	—	No

Table 4 — Identifiers for thermal characteristics of a building component

Name	Symbol	Unit	Value	Range	Origin	Varying
design thermal conductivity	λ	W/(m·K)	—	0 to 200	ISO 10456	No

Table 5 — Identifiers for tabulated and conventional values

Name	Symbol	Unit	Value	Range	Origin	Varying
external surface resistance	R_{se}	m^2·K/W	0,04	—	6.8	No
internal surface resistance	R_{si}	m^2·K/W	—	0,1 to 0,2	6.8	No
thermal resistance of unheated spaces	R_u	m^2·K/W	—	0,06 to 0,3	6.10	No
thermal resistance of air layer	R_a	m^2·K/W	—	—	6.9	No
thermal resistance of unventilated air layer	$R_{tot;u}$	m^2·K/W	—	0 to 0,23	6.9	No
thermal resistance of ventilated air layer	$R_{tot;c}$	m^2·K/W	—	—	6.9	No
radiative coefficient for a black-body surface	h_{r0}	W/(m^2·K)	5,1	—	Annex C	No
convective coefficient; internal surface	$h_{c;i}$	W/(m^2·K)	—	0,7 to 5,0	Annex C	No
convective coefficient; external surface	$h_{c;e}$	W/(m^2·K)	20	—	Annex C	No
radiative coefficient; internal surface	$h_{r;i}$	W/(m^2·K)	4,59	—	Annex D	No
radiative coefficient; external surface	$h_{r;e}$	W/(m^2·K)	5,13	—	Annex D	No
hemispherical emissivity of surface	ε	—	0,9	—	Annex D	No

Table 6 gives the identifier for a constant.

Table 6 — Identifier for constant

Name	Symbol	Unit	Value	Range	Origin	Varying
Stefan-Boltzmann constant	σ	W/(m^2·K^4)	$5{,}67 \times 10^{-8}$	—	—	No

Input data about products that are required for the calculation of thermal transmittance described in this document shall be the data supplied by the manufacturer if they are declared according to relevant EN or EN ISO product standards (in the CEN area) or equivalent ISO or national standards (outside the CEN area).

Other input data, e.g. dimensional data of layers or components required for the calculation method described in this document, shall be acquired from the design of building elements with all details as specified in this document.

6.4 Principles of the simplified calculation procedure

The principle of the calculation method is as follows:

a) obtain the thermal resistance of each thermally homogeneous or inhomogeneous part of the building element;

b) combine these individual resistances to obtain the total thermal resistance of the building element, including (where appropriate) the effect of surface resistances;

c) calculate the thermal transmittance as given in 6.5.2;

d) corrections shall be applied to the thermal transmittance in accordance with Annex F if the total correction exceeds 3 % of the calculated thermal transmittance.

Thermal resistances of individual homogeneous layers of building element are obtained according to 6.7.1.1 and the total thermal resistance of the building element is calculated according to 6.7.1.2.

Thermal resistances of individual materials in inhomogeneous layers of a building element are obtained according to 6.7.1.1 and then used as arithmetic mean of the upper and lower limits of thermal resistance according to 6.7.2.2. The total thermal resistance of the building element is calculated according to 6.7.2.

The values of surface resistance given in 6.8 are appropriate in most cases. Annex C gives detailed procedures for low emissivity surfaces, specific external wind speeds and non-planar surfaces.

Air layers up to 0,3 m thickness may be regarded as thermally homogeneous for the purposes of this document. Values of the thermal resistance of large unventilated air layers with high emissivity surfaces are given in 6.9.2. Annex D provides procedures for other cases.

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 6.10 for treating an unheated space as a thermal resistance.

NOTE Calculation of heat flow rates is 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 C.

6.5 Thermal transmittance

6.5.1 By detailed calculation method

In the case of the detailed calculation method, the thermal transmittance is the output from a calculation according to ISO 10211.

6.5.2 By simplified calculation method

In the case of the simplified calculation method, the thermal transmittance is given by:

$$U = \frac{1}{R_{tot}} \tag{1}$$

where

U is the thermal transmittance, in W/(m^2·K);

R_{tot} is the total thermal resistance, determined according to 6.7, in m^2·K/W.

Corrections to the thermal transmittance, as appropriate to the building element concerned, shall be calculated in accordance with Annex F. If, however, the total correction as obtained by Formula (F.2) is less than 3 % of U, the corrections need not be applied.

If the thermal transmittance is presented as a final result, it shall be rounded to two significant figures, and information shall be provided on the input data used for the calculation.

6.6 Thermal resistance

The thermal resistance of the component is given by:

$$R_{c;op} = \frac{1}{U} - R_{si} - R_{se} \quad (2)$$

where

$R_{c;op}$ is the thermal resistance of the component, in $m^2 \cdot K/W$;

R_{si} is the thermal resistance of internal surface, in $m^2 \cdot K/W$;

R_{se} is the thermal resistance of external surface, in $m^2 \cdot K/W$;

U is the thermal transmittance, determined according to 6.5.

The surface resistances are the same as those used to calculate the thermal transmittance.

Formula (2) applies to the detailed method and to the simplified method.

If the thermal resistance is presented as a final result, it shall be rounded to two decimal places, and information shall be provided on the input data used for the calculation.

NOTE $R_{c;op}$ is the thermal resistance of the component from surface to surface, without surface resistances.

6.7 Total thermal resistance

6.7.1 Thermal resistance of homogeneous components

6.7.1.1 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

$$R = \frac{d}{\lambda} \quad (3)$$

where

R is the thermal resistance, in $m^2 \cdot K/W$;

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

λ is the design thermal conductivity of the material, in $W/(m \cdot K)$.

Values of λ shall be calculated in accordance with ISO 10456 if based on measured data. In other cases, λ is obtained from tabulated values, see ISO 10456.

A template for tabulated values is given in Table A.2, with an informative default list in Table B.2.

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 makes 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.