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Thermal performance of building components — Dynamic thermal characteristics — Calculation methods

Performance thermique des composants de bâtiment — Caractéristiques thermiques dynamiques — 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 13786 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 13786:2007), which has been technically revised.

The changes in the third edition are mostly editorial. This document has been re-drafted according to CEN/TS 16629:2014.

This corrected version of ISO 13786 incorporates the following correction:

— In Formula (C.5) the symbol É^2 has been corrected to ω^2.

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.

This document provides calculation methods for the dynamic thermal characteristics of a building component. These characteristics describe the thermal behaviour of the component when it is subject to variable boundary conditions, i.e. variable heat flow rate or variable temperature on one or both of its boundaries. In this document, only sinusoidal boundary conditions are considered: boundaries are submitted to sinusoidal variations of temperature or heat flow rate.

The properties considered are thermal admittances and thermal dynamic transfer properties, relating cyclic heat flow rate to cyclic temperature variations. Thermal admittance relates heat flow rate to temperature variations on the same side of the component. Thermal dynamic transfer properties relate physical quantities on one side of the component to those on the other side. From the aforementioned properties, it is possible to define the heat capacity of a given component which quantifies the heat storage property of that component.

The dynamic thermal characteristics defined in this document can be used in product specifications of complete building components.

The dynamic thermal characteristics can also be used in the calculation of:

— the internal temperature in a room,

— the daily peak power and energy needs for heating or cooling, and

— the effects of intermittent heating or cooling, etc.

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* M2–9) 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		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										
9	Calculated energy performance		Building dynamics (thermal mass)	ISO 13786	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.

Thermal performance of building components — Dynamic thermal characteristics — Calculation methods

1 Scope

This document specifies the characteristics related to the dynamic thermal behaviour of a complete building component and provides methods for their calculation. It also specifies the information on building materials required for the use of the building component. Since the characteristics depend on the way materials are combined to form building components, this document is not applicable to building materials or to unfinished building components.

The definitions given in this document are applicable to any building component. A simplified calculation method is provided for plane components consisting of plane layers of substantially homogeneous building materials.

Annex C provides simpler methods for the estimation of the heat capacities in some limited cases. These methods are suitable for the determination of dynamic thermal properties required for the estimation of energy consumption. These approximations are not appropriate, however, for product characterization.

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 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 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 Definitions valid for any component

3.1.1
building element
major part of a building

EXAMPLE Wall, floor or roof.

3.1.2
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.

3.1.3
thermal zone of a building
part of a building throughout which the internal temperature is assumed to have negligible spatial variations

Note 1 to entry: A component separates two zones, designated in this document by *m* and *n*.

Note 2 to entry: The external environment can also be considered a zone.

3.1.4
sinusoidal conditions
conditions in which the variations of the temperature and heat flows around their long term average values are described by a sine function of time

Note 1 to entry: Using complex numbers, the temperature in zone *n* can be described by Formula (1) and the heat flow by Formula (2):

$$\theta_n(t) = \bar{\theta}_n + \left|\hat{\theta}_n\right| \times \cos\left(\omega \times t + \psi\right) = \bar{\theta}_n + \frac{1}{2} \times \left[\hat{\theta}_{+n} \times e^{\mathrm{j}\omega t} + \hat{\theta}_{-n} \times e^{-\mathrm{j}\omega t}\right] \quad (1)$$

$$\Phi_n(t) = \bar{\Phi}_n + \left|\hat{\Phi}_n\right| \times \cos\left(\omega \times \cdot t + \varphi\right) = \bar{\Phi}_n + \frac{1}{2} \times \left[\hat{\Phi}_{+n} \times e^{\mathrm{j}\omega t} + \hat{\Phi}_{-n} \times e^{-\mathrm{j}\omega t}\right] \quad (2)$$

where

$\bar{\theta}_n$ and $\bar{\Phi}_n$ are average values of temperature and heat flow;

$\left|\hat{\theta}_n\right|$ and $\left|\hat{\Phi}_n\right|$ are amplitudes of temperature and heat flow variations;

$\hat{\theta}_{\pm n}$ and $\hat{\Phi}_{\pm n}$ are complex amplitudes defined by

$$\hat{\theta}_{\pm n} = \left|\hat{\theta}_n\right| e^{\pm \mathrm{j}\psi} \quad \text{and} \quad \hat{\Phi}_{\pm n} = \left|\hat{\Phi}_n\right| e^{\pm \mathrm{j}\varphi} \quad (3)$$

where ω is the angular frequency of the variations.

3.1.5
periodic thermal conductance
L_{mn}
complex number relating the periodic heat flow into a component to the periodic temperatures on either side of it under sinusoidal conditions

Note 1 to entry: Another representation of the concept:

$$\hat{\Phi}_m = L_{mm} \times \hat{\theta}_m - L_{mn} \times \hat{\theta}_n \tag{4}$$

Note 2 to entry: L_{mm} relates the periodic heat flow on side m to the periodic temperature on side m when the temperature amplitude on side n is zero. L_{mn} relates the periodic heat flow on side m to the periodic temperature on side n when the temperature amplitude on side m is zero.

Note 3 to entry: As a convention within this document, the heat flow rate is defined as positive when it enters the surface of the component.

3.1.6
heat capacity
modulus of the net periodic thermal conductance divided by the angular frequency

Note 1 to entry: Another representation of the concept:

$$C_m = \frac{1}{\omega} \times \left| L_{mm} - L_{mn} \right| \tag{5}$$

where $\omega = \frac{2\pi}{T}$ and T is the period of variation in seconds.

3.1.7
time shift
Δt
period of time between the maximum amplitude of a cause and the maximum amplitude of its effect

3.2 Definitions valid only for one dimensional heat flow

3.2.1
plane component
component for which the smallest curvature radius is at least five times its thickness

3.2.2
homogeneous material layer
layer of material in which the largest size of inhomogenities does not exceed one fifth of the thickness of the layer

3.2.3
thermal admittance
complex quantity defined as the complex amplitude of the density of heat flow rate through the surface of the component adjacent to zone m, divided by the complex amplitude of the temperature in the same zone when the temperature on the other side is held constant

Note 1 to entry: Another representation of the concept:

$$Y_{mm} = \frac{\hat{q}_m}{\hat{\theta}_m} \tag{6}$$

3.2.4
periodic thermal transmittance
complex quantity defined as the complex amplitude of the density of heat flow rate through the surface of the component adjacent to zone *m*, divided by the complex amplitude of the temperature in zone *n* when the temperature in zone *m* is held constant

Note 1 to entry: Another representation of the concept:

$$Y_{mn} = -\frac{\hat{q}_m}{\hat{\theta}_n} \tag{7}$$

3.2.5
areal heat capacity
heat capacity divided by area of element

Note 1 to entry: Another representation of the concept:

$$\kappa_m = \frac{C_m}{A} = \frac{1}{\omega} \times \left| Y_{mm} - Y_{mn} \right| \tag{8}$$

Note 2 to entry: Using Formula (8), the heat capacities are then:

$$C_m = A \times \kappa_m \tag{9}$$

Note 3 to entry: There are two thermal admittances and two heat capacities for a component separating two zones, all of which depend on the period of the thermal variations.

3.2.6
decrement factor
ratio of the modulus of the periodic thermal transmittance to the steady-state thermal transmittance *U*

Note 1 to entry: Another representation of the concept:

$$f = \frac{\left|\hat{q}_m\right|}{\left|\hat{\theta}_n\right| \times U} = \frac{\left|Y_{mn}\right|}{U} \tag{10}$$

where $m \neq n$.

3.2.7
periodic penetration depth
δ
depth at which the amplitude of the temperature variations are reduced by the factor "*e*" in a homogeneous material of infinite thickness subjected to sinusoidal temperature variations on its surface

Note 1 to entry: Another representation of the concept:

$$\delta = \sqrt{\frac{\lambda \times T}{\pi \times \rho \times c}} \tag{11}$$

Note 2 to entry: *e* is the base of natural logarithms; *e* = "2,718..."

3.2.8
heat transfer matrix
Z
matrix relating the complex amplitudes of temperature and heat flow rate on one side of a component to the complex amplitudes of temperature and heat flow rate on the other side

Note 1 to entry: Another representation of the concept:

$$Z = \begin{pmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} \hat{\theta}_2 \\ \hat{q}_2 \end{pmatrix} = Z \times \begin{pmatrix} \hat{\theta}_1 \\ \hat{q}_1 \end{pmatrix} \tag{12}$$

3.3 Other

3.3.1
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]

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
C	heat capacity	J/K
L_{mn}	periodic thermal conductance	W/K
R	thermal resistance	m^2·K/W
T	period of the variations	s
U	thermal transmittance under steady-state boundary conditions	W/(m^2·K)
Y_{mm}	thermal admittance	W/(m^2·K)
Y_{mn}	periodic thermal transmittance	W/(m^2·K)
Z	heat transfer matrix environment to environment	—
Z_{mn}	element of the heat transfer matrix	—
a	thermal diffusivity	m^2/s
c	specific heat capacity	J/(kg·K)
d	thickness of a layer	m
f	decrement factor	—
j	unit on the imaginary axis for a complex number; $\mathrm{j} = \sqrt{-1}$	—
q	density of heat flow rate	W/m^2
t	time	s or h
x	distance through the component	m
Δt	time shift: time lead (if positive), or time lag (if negative)	s or h
δ	periodic penetration depth of a heat wave in a material	m
Φ	heat flow rate	W
ξ	ratio of the thickness of the layer to the penetration depth	—
κ	areal heat capacity	J/(m^2·K)
λ	design thermal conductivity	W/(m·K)
ρ	density	kg/m^3

Symbol	Quantity	Unit
θ	temperature	°C
ω	angular frequency; $\omega = \dfrac{2\pi}{T}$	rad/s
φ, ψ	phase differences	rad

4.2 Subscripts

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

a	air layer
f	related to decrement factor
m	component
mm, mn	effect at side m, due to a cause at side m, n
se	external surface
si	internal surface
m, *n*	for the thermal zones

4.3 Specific symbols

For the purposes of this document, the following specific symbols apply.

^	complex amplitude
–	mean value
| |	modulus of a complex number
arg	argument of a complex number

5 Description of the method

5.1 Output

The output of this document is the non-steady-state thermal characteristics of a building component.

5.2 General description

The calculation method uses complex numbers representing a sinusoidal variation of temperature and heat flow to calculate the dynamic thermal properties of a building component. These functions are an approximation to daily variations on an hourly basis or to annual variation on a monthly basis.

6 Calculation of dynamic thermal properties

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
Heat capacity	C_m	J/K	M2–2	≥0	No
Thermal admittance	Y_{mm}	W/(m²·K)		≥0	No
Periodic thermal transmittance	Y_{mn}	W/(m²·K)		≥0	No
Areal (specific) heat capacity	κ_m	J/(m²·K)	M2–2	≥0	No
Decrement factor	f	—		≥0	No
Periodic penetration depth	δ	m		≥0	No
Heat transfer matrix	Z	—		≥0	No
Element of the heat transfer matrix	Z_{mn}	—		≥0	No

6.2 Calculation time intervals

The input, the method and the output data are not time-dependent and assumed to be independent of actual conditions, such as indoor temperature or effect of wind or solar radiation. However, the results depend on the period of temperature variations used in the calculation (see 6.4).

6.3 Input data

Tables 3 to 6 list identifiers for input data required for the calculation.

Table 3 — Identifiers for geometric characteristics

Name	Symbol	Unit	Value	Range	Origin	Varying
Area of a building component	A	m²		≥0		No
Thickness of each layer of a building component	d	m		≥0		No

Table 4 — Identifiers for thermal characteristics of building component

Name	Symbol	Unit	Value	Range	Origin	Varying
Design thermal conductivity	λ	W/(m·K)		0 to 10	ISO 10456	No
Density	ρ_m	kg/m³		0 to ∞		No
Specific heat capacity	c_m	J/(kg·K)		0 to ∞		No

Table 5 — Identifiers for tabulated and conventional values

Name	Symbol	Unit	Value	Range	Origin	Varying
External surface resistance	R_{se}	m²·K/W			ISO 6946	No
Internal surface resistance	R_{si}	m²·K/W			ISO 6946	No
Thermal resistance of air layer	R_a	m²·K/W			ISO 6946	No

Table 6 — Identifier for period of temperature variations

Name	Symbol	Unit	Value	Range	Origin	Varying
Period of temperature variations	T	s	≥0	No		No

6.4 Period of the thermal variations

The definition of dynamic thermal characteristics and the formulae for their calculation are valid for any period of thermal variations.

The values of dynamic thermal characteristics depend on the periods. If more than one period is considered, an additional suffix shall be added to all quantities affected so as to distinguish between the values for different periods.

Practical time periods are

— one hour (3 600 s), which corresponds to very short time variations, such as those resulting from temperature control systems,

— one day (86 400 s), corresponding to daily meteorological variations and temperature setback,

— one week (604 800 s), corresponding to longer term averaging of the building, and

— one year (31 536 000 s), useful for the treatment of heat transfer through the ground.

6.5 Heat capacity

Two methods are defined for calculation of the heat capacity of a building component:

— a detailed calculation according to Clause 8;

— a simplified calculation according to Annex C.

A template for defining restrictions on the use of the simplified method is given in Table A.2, with default choices in Table B.2.

7 Heat transfer matrix of a multi-layer component

7.1 General

The procedure in 7.2 applies to building components consisting of plane homogeneous layers. Thermal bridges usually present in such building components do not usually affect significantly the dynamic thermal characteristics, and are neglected.

The calculation of dynamic thermal characteristics of non-plane components and of components containing very important thermal bridges shall be made by solving the equation of heat transfer under periodic boundary conditions. For this purpose, the rules for modelling the component as given in ISO 10211 shall be used together with numerical methods, such as finite difference and finite element techniques.

7.2 Procedure

The procedure is as follows:

a) identify the materials comprising the layers of the building component and the thickness of these layers, and determine the thermal characteristics of the materials;

b) specify the period of the variations at the surfaces;

c) calculate the penetration depth for the material of each layer;

d) determine the elements of the heat transfer matrix for each layer;

e) multiply the layer heat transfer matrices, including those of the boundary layers, in the correct order, so as to obtain the transfer matrix of the component.

7.3 Heat transfer matrix of a homogeneous layer

The periodic penetration depth for the material of the layer, δ, is calculated from its thermal properties and the period T using Formula (11).

The ratio of the thickness of the layer to the penetration depth is then

$$\xi = \frac{d}{\delta} \tag{13}$$

The matrix elements, Z_{mn}, are calculated as follows:

$$Z_{11} = Z_{22} = \cosh(\xi) \times \cos(\xi) + \mathrm{j} \times \sinh(\xi) \times \sin(\xi);$$

$$Z_{12} = -\frac{\delta}{2\lambda} \times \left\{ \sinh(\xi) \times \cos(\xi) + \cosh(\xi) \times \sin(\xi) + \mathrm{j} \times \left[\cosh(\xi) \times \sin(\xi) - \sinh(\xi) \times \cos(\xi) \right] \right\}$$

$$Z_{21} = -\frac{\lambda}{\delta} \times \left\{ \sinh(\xi) \times \cos(\xi) - \cosh(\xi) \times \sin(\xi) + \mathrm{j} \times \left[\sinh(\xi) \times \cos(\xi) + \cosh(\xi) \times \sin(\xi) \right] \right\} \tag{14}$$

7.4 Heat transfer matrix of plane air cavities

The specific heat capacity of such layers is neglected. Hence, if R_a is the thermal resistance of the air layer, including convection, conduction and radiation, its heat transfer matrix is

$$Z_a = \begin{pmatrix} 1 & -R_a \\ 0 & 1 \end{pmatrix} \tag{15}$$

The thermal resistance of the air layer shall be calculated in accordance with ISO 6946.

7.5 Heat transfer matrix of a building component

The heat transfer matrix of the building component from surface to surface is

$$Z = \begin{pmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{pmatrix} = Z_N \, Z_{N-1} \ldots Z_3 \, Z_2 \, Z_1 \tag{16}$$

where Z_1, Z_2, Z_3, ..., Z_N, are the heat transfer matrices of the various layers of the building component, beginning from layer 1. As a convention for building envelope components, layer 1 shall be the innermost layer.

The heat transfer matrix from environment to environment through the building component is

$$Z_{ee} = Z_{s2} \, Z \, Z_{s1} \tag{17}$$

where Z_{s1} and Z_{s2} are the heat transfer matrices of the boundary layers, given by

$$Z_s = \begin{pmatrix} 1 & -R_s \\ 0 & 1 \end{pmatrix} \tag{18}$$

where R_s is the surface resistance of the boundary layer, including convection and radiation. Values of surface resistance shall be in accordance with ISO 6946.

In most cases, the heat transfer matrix and the dynamic characteristics of a building component shall be calculated using the surface resistance values appropriate to the intended orientation of the component. If the orientation of the component is not known, the calculations shall be done for vertical orientation (heat flow horizontal). For certain applications where boundary layers are taken into account separately, the periodic heat capacity of the component should be calculated omitting the boundary layers.

8 Dynamic thermal characteristics

8.1 Characteristics for any component

The dynamic thermal characteristics of any component are four periodic thermal conductances, L_{mn} (see 3.1.5), and two heat capacities, C_m (see 3.1.6).

8.2 Characteristics for components consisting of plane and homogeneous layers

8.2.1 Thermal admittances and periodic thermal conductances

The thermal admittances are

$$Y_{11} = -\frac{Z_{11}}{Z_{12}} \quad \text{and} \quad Y_{22} = -\frac{Z_{22}}{Z_{12}} \tag{19}$$

where Y_{11} is for the internal side of the component, while Y_{22} is for the external side

The time shift of admittance is

$$\Delta t_Y = \frac{T}{2\pi} \times \arg\left(Y_{mm}\right) \tag{20}$$

with the argument evaluated in the range 0 to 2π.

8.2.2 Modified admittance for internal partitions

For internal partitions within a building, where the temperature variations are the same on either side of the partition, the periodic heat flow is related to the periodic temperature variations by a modified admittance:

$$Y_{mm}^{*} = Y_{mm} - Y_{mn} \tag{21}$$

where Y_{mn} is the periodic thermal transmittance.

8.2.3 Areal heat capacities

The areal heat capacities are

$$\kappa_1 = \frac{T}{2\pi} \times \left|\frac{Z_{11} - 1}{Z_{12}}\right| \tag{22}$$

and

$$\kappa_2 = \frac{T}{2\pi} \times \left|\frac{Z_{22} - 1}{Z_{12}}\right| \tag{23}$$

Formulae (22) and (23) apply to both external elements and to internal partitions.

NOTE For an internal partition, $\kappa_m = \frac{\left|Y_{mm}^{*}\right|}{\omega}$.

8.2.4 Periodic thermal transmittance and decrement factor

The periodic thermal transmittance is given by

$$Y_{12} = -\frac{1}{Z_{12}} \tag{24}$$

and the decrement factor is given by

$$f = \frac{|Y_{12}|}{U_0} \tag{25}$$

where the thermal transmittance, U_0, is calculated in accordance with ISO 6946, ignoring any thermal bridges.

NOTE U_0 is calculated ignoring thermal bridges for consistency with the calculation of the dynamic characteristics (see 7.1).

The decrement factor is always less than 1.

The time shift of the periodic thermal transmittance is:

$$\Delta t_f = \frac{T}{2\pi} \times \arg(Z_{12}) \tag{26}$$

with the argument evaluated in the range -2π to 0.

9 Report

9.1 Calculation report

The calculation report shall include a description of the building component, its normal use (part of the envelope or internal component) and enumeration of zones in contact with it.

Each homogeneous part shall be clearly defined with dimensions and identification of the material used in the part, as well as the thermal conductivity, the density and the specific heat capacity used for the calculations.

The report shall provide, for any component, the periodic thermal conductances and the heat capacities, together with the period, T, used for the calculations.

In addition, for plane components made of homogeneous layers, the report shall contain:

— the area of the element;

— a list of the layers beginning with side 1; side 1 adopted for the calculation shall be clearly designated; for building envelope components, side 1 shall be that of the innermost layer;

— the values of the surface resistances, R_{si} and R_{se}, used for the calculation;

— the four elements of the transfer matrix, Z; these complex numbers are given by their modulus and argument, in angular units; the arguments may also be converted into the corresponding time shifts;

— the two thermal admittances, described by their modulus and arguments;

— the decrement factor;

— the thermal transmittance, U_0, used for the calculation of the decrement factor; the thermal transmittance including thermal bridges, calculated in accordance with ISO 6946, shall also be included where possible: if that is not possible, it shall be made clear in the report that the thermal transmittance does not include thermal bridges and is not suitable for steady-state heat transfer calculations.

The heat transfer matrix of the reversed component shall also be provided for building envelope components which could be installed with either side in contact with the external environment.

If the calculation is performed for several periods, the results shall be provided for each period.

9.2 Summary of results

If only some of the characteristics are extracted from the calculation report for use as product specifications, then these shall include at least the heat capacities and the decrement factor for a period of one day.

For components where the decrement factor cannot be calculated, the periodic thermal conductance is given instead of the decrement factor.

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

In this document, there is no need to specify choices in methods. A.3 is kept to maintain uniformity between all EPB standards.

A.4 Input data and choices

Table A.2 — Simplified method for heat capacity (see 6.5)

Item	Choice
Any restriction on the use of the simplified method?	Yes/No
If yes, formulate the restrictions.	Restrictions: .....
Maximum effective thickness for specific materials.	(Give list)