INTERNATIONAL STANDARD

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Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods

Performance hygrothermique des composants et parois de bâtiments — Température superficielle intérieure permettant d'éviter l'humidité superficielle critique et la condensation dans la masse — Méthodes de calcul

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Contents

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 13788 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 2, *Calculation methods* in cooperation with CEN/TC 89, *Thermal performance of buildings and building components*.

This second edition cancels and replaces the first edition (ISO 13788:2001), which has been technically revised.

Introduction

Moisture transfer is a very complex process and the knowledge of moisture transfer mechanisms, material properties, initial conditions and boundary conditions is often limited. Therefore this International Standard lays down simplified calculation methods, which assume that moisture transport is by vapour diffusion alone and use monthly climate data. The standardization of these calculation methods does not exclude use of more advanced methods. If other sources of moisture, such as rain penetration or convection, are negligible, the calculations will normally lead to designs well on the safe side and if a construction fails a specified design criterion according to this procedure, more accurate methods may be used to show that the design will pass.

This International Standard deals with:

a) the critical surface humidity likely to lead to problems such as mould growth on the internal surfaces of buildings,

b) interstitial condensation within a building component, in:

  — heating periods, where the internal temperature is usually higher than outside;

  — cooling periods, where the internal temperature is usually lower than the outside;

  — cold stores, where the internal temperature is always lower than outside.

c) an estimate of the time taken for a component, between high vapour resistance layers, to dry, after wetting from any source, and the risk of interstitial condensation occurring elsewhere in the component during the drying process.

This International Standard does not cover other aspects of moisture, e.g. ground water and ingress of precipitation.

In some cases, airflow from the interior of the building into the structure is the major mechanism for moisture transport, which can increase the risk of condensation problems very significantly. This International Standard does not address this issue; where it is felt to be important, more advanced assessment methods should be considered.

The limitations on the physical processes covered by this International Standard mean that it can provide a more robust analysis of some structures than others. The results will be more reliable for lightweight, airtight structures that do not contain materials that store large amounts of water. They will be less reliable for structures with large thermal and moisture capacity and which are subject to significant air leakage.

Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods

1 Scope

This International Standard gives simplified calculation methods for:

a) The internal surface temperature of a building component or building element below which mould growth is likely, given the internal temperature and relative humidity. The method can also be used to assess the risk of other internal surface condensation problems.

b) The assessment of the risk of interstitial condensation due to water vapour diffusion. The method used does not take account of a number of important physical phenomena including:

- the variation of material properties with moisture content;
- capillary suction and liquid moisture transfer within materials;
- air movement from within the building into the component through gaps or within air spaces;
- the hygroscopic moisture capacity of materials.

Consequently, the method is applicable only where the effects of these phenomena can be considered to be negligible.

c) The time taken for water, from any source, in a layer between two high vapour resistance layers to dry out and the risk of interstitial condensation occurring elsewhere in the component during the drying process.

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 6946:2007, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

ISO 9346, *Hygrothermal performance of buildings and building materials — Physical quantities for mass transfer — Vocabulary*

ISO 15927-1, *Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 1: Monthly means of single meteorological elements*

3 Terms and definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9346 and the following apply.

3.1.1
monthly mean temperature
mean temperature calculated from hourly values or the daily maximum and minimum temperature over a month

3.1.2
temperature factor at the internal surface
difference between the temperature of the internal surface and the external air temperature, divided by the difference between the internal operative temperature and the external air temperature, calculated with a surface resistance at the internal surface R_{si}:

$$f_{R_{si}} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e}$$

Note 1 to entry: The operative temperature is taken as the arithmetic mean value of the internal air temperature and the mean radiant temperature of all surfaces surrounding the internal environment.

Note 2 to entry: Methods of calculating the temperature factor in complex constructions are given in ISO 10211.

3.1.3
design temperature factor at the internal surface
minimum acceptable temperature factor at the internal surface:

$$f_{R_{si,min}} = \frac{\theta_{si,min} - \theta_e}{\theta_i - \theta_e}$$

3.1.4
minimum acceptable temperature
lowest internal surface temperature before mould growth may start

3.1.5
mean annual minimum temperature
mean of the lowest temperature recorded in each year of a set of at least ten years' data

3.1.6
internal moisture excess
rate of moisture production in a space divided by the air change rate and the volume of the space:

$$\Delta \nu = \nu_i - \nu_e = G / (n \cdot V)$$

3.1.7
water vapour diffusion-equivalent air layer thickness
thickness of a motionless air layer which has the same water vapour resistance as the material layer in question: $s_d = \mu \cdot d$

3.1.8
relative humidity
ratio of the vapour pressure to the saturated vapour pressure at the same temperature:

$$\varphi = \frac{p}{p_{sat}}$$

3.1.9
critical surface humidity
relative humidity at the surface that leads to deterioration of the surface, specifically mould growth

3.1.10
heating period
external climate that leads to risk of condensation when a building is being heated, so that the internal temperature and vapour pressure are higher than outside

3.1.11
cooling period
external climate that leads to risk of condensation when a building is being cooled, so that the internal temperature and vapour pressure are lower than outside

3.2 Symbols and units

Symbol	Quantity	Unit
D	water vapour diffusion coefficient in a material	m²/s
D_0	water vapour diffusion coefficient in air	m²/s
G	internal moisture production rate	kg/h
M_a	accumulated moisture content per area at an interface	kg/m²
R	thermal resistance	m²·K/W
R_v	gas constant for water vapour = 462	Pa·m³/(K·kg)
T	thermodynamic temperature	K
U	thermal transmittance of component or element	W/(m²·K)
V	internal volume of building	m³
Z_p	water vapour diffusion resistance with respect to partial vapour pressure	m²·s·Pa/kg
Z_v	water vapour diffusion resistance with respect to humidity by volume	s/m²
d	material layer thickness	m
f_{Rsi}	temperature factor at the internal surface	-
$f_{Rsi,min}$	design temperature factor at the internal surface	-
g	density of water vapour flow rate	kg/(m²·s)
n	air change rate	h⁻¹
p	water vapour pressure	Pa
q	density of heat flow rate	W/m²
s_d	water vapour diffusion-equivalent air layer thickness	m
t	time	s
w	moisture content mass by volume	kg/m³
δ_p	water vapour permeability of material with respect to partial vapour pressure	kg/(m·s·Pa)
δ_0	water vapour permeability of air with respect to partial vapour pressure	kg/(m·s·Pa)
v	humidity of air by volume	kg/m³
Δv	internal moisture excess, $v_i - v_e$	kg/m³
Δp	internal vapour pressure excess, $p_i - p_e$	Pa
φ	relative humidity	-
λ	thermal conductivity	W/(m·K)
μ	water vapour resistance factor	-
θ	Celsius temperature	°C
$\theta_{si,min}$	minimum acceptable surface temperature	°C

3.3 Subscripts

an	annual	m	mean
c	condensation	n	interface
cr	critical value	s	surface
e	external air	sat	value at saturation
ev	evaporation	se	external surface
eq	equivalent (outside temperature)	si	internal surface
i	internal air	T	total over the whole component or element
min	minimum value		

4 Input data for the calculations

4.1 Material and product properties

For the calculations, design values shall be used. Design values in product or material specifications or the tabulated design values given in the standards referred to in Table 1 may be used.

Table 1 — Material and product properties

Property	Symbol	Design values
Thermal conductivity Thermal resistance	λ R	Obtained or determined in accordance with ISO 10456.
Water vapour resistance factor Water vapour diffusion-equivalent air layer thickness	μ s_d	Obtained from ISO 10456 or determined in accordance with ISO 12572.

Thermal conductivity, λ, and water vapour resistance factor, μ, are applicable to homogenous materials and thermal resistance, R, and water vapour diffusion-equivalent air layer thickness, s_d, apply primarily to composite products or products without well-defined thickness.

For air layers, R is taken from ISO 6946 and s_d is assumed to be 0,01 m, independent of air layer thickness and inclination.

4.2 External boundary conditions

4.2.1 Location

Unless otherwise specified, the external conditions used shall be representative of the location of the building, taking account of altitude where appropriate.

NOTE Unless other information is available (for example in national standards), it can be assumed that temperature falls by 1 K for every 200 m increase in altitude.

4.2.2 Time period for climatic data

For the calculation of the risk of surface mould growth or the assessment of structures for the risk of interstitial condensation, monthly mean values, derived using the methods described in ISO 15927-1, or in national standards, shall be used.

In the absence of national data or standards, the mean monthly temperatures shall be those likely to occur once in 10 years, obtained from local climate records. If these data are not available, 2 K may be subtracted from the monthly mean temperatures for an average year for calculations in a heating climate, or 2 K added to the monthly mean temperatures for an average year in a cooling climate.

For calculations of the risk of surface condensation on low thermal inertia elements such as windows and their frames, the average, taken over several years, of the lowest daily mean temperature in each year shall be used in the absence of any national standards.

4.2.3 External temperature

The following temperatures shall be used for the calculations.

a) For calculations of walls exposed to the outside, the external air temperature as specified in 4.2.1 and 4.2.2 shall be used.

b) For calculation of solid ground floors or walls below the ground, incorporate 2 m of soil below the floor in the calculation. The monthly mean temperatures in the ground below this may be estimated with the following steps:

— Take the twelve monthly mean external air temperatures: θ_m

— Average these to give the annual mean external air temperature: θ_{an}

— For each month calculate the average of the θ_m and θ_{an}: $(\theta_{an}+\theta_m)/2$

— Displace the calculated values by one month, so the January value becomes February etc.

— If necessary, more detailed calculation of ground temperature may be carried out with the methods in ISO 13370.

c) For calculations of suspended floors algorithms for the calculation of monthly subfloor temperatures from the internal and external monthly temperatures are given in Annex E of ISO 13370

d) For calculations of roofs the monthly mean equivalent outside temperature, $\overline{\theta_{eq}}$, which takes account of solar gain and cooling by long wave radiation, should be used; $\overline{\theta_{eq}}$ can be calculated using the methodology given in ISO 13790. As a simplified case, $\overline{\theta_{eq}}$ can be taken by subtracting 2 K from every monthly mean external air temperature.

4.2.4 External humidity

4.2.4.1 External air

To define the external air humidity conditions, use vapour pressure, p_e.

Monthly mean vapour pressure may be calculated from the mean temperature and relative humidity using Formula (1).

$$\overline{p_e} = \overline{\varphi_e}\, p_{sat}\left(\overline{\theta_e}\right) \tag{1}$$

For calculations of the risk of surface condensation on low thermal inertia elements such as windows and their frames, the external relative humidity corresponding to the temperatures defined in 4.2.2 shall be used.

NOTE In some climates the relative humidity associated with the mean annual minimum temperature can be assumed to be 0,85.

4.2.4.2 Humidity conditions in the ground

Assume saturation (φ = 1).

4.3 Internal boundary conditions

4.3.1 Internal air temperature

Use values according to the expected use of the building.

NOTE Annex A gives a method for estimating internal air temperature from the external temperature.

4.3.2 Internal humidity

The internal air humidity can be either

a) obtained from

$$p_i = p_e + \Delta p \quad (2)$$

Take values of Δp according to the expected use of the building.

Δp may be derived from the internal moisture excess, Δv, using

$$\Delta p = \Delta v \, R_v \, T_i = \frac{G}{nV} R_v \, T_i \quad (3)$$

Values of Δp for a range of building types may be found in Appendix A.

or

b) given as a monthly mean value φ_i when the internal relative humidity is known.

NOTE Annex A gives a method for estimating internal relative humidity from the external air temperature.

c) given as a constant φ_i when the internal relative humidity is kept constant e.g. by air-conditioning.

4.4 Surface resistances

4.4.1 Heat transfer

The value of R_{se} shall be taken as 0,04 m^2·K/W.

For condensation or mould growth on opaque surfaces, an internal surface thermal resistance of 0,25 m^2·K/W shall be taken to represent the effect of corners, furniture, curtains or suspended ceilings, if there are no national standards.

The values of R_{si} given in Table 2 shall be used for the assessment of interstitial condensation, or surface condensation on windows and doors.

Table 2 — Internal thermal resistances for the assessment of interstitial condensation, or surface condensation on windows and doors

Direction of heat flow	Thermal resistance m2·K/W
Upwards	0,10
Horizontal	0,13
Downwards	0,17

4.4.2 Water vapour transfer

The surface water vapour resistance is assumed to be negligible in the calculations in accordance with this International Standard.

5 Calculation of surface temperature to avoid critical surface humidity

5.1 General

This clause specifies a method to design the building envelope to prevent the adverse effects of critical surface humidity, e.g. mould growth.

NOTE Surface condensation can cause damage to unprotected building materials that are sensitive to moisture. It can be accepted temporarily and in small amounts, e.g. on windows and tiles in bathrooms, if the surface does not absorb the moisture and adequate measures are taken to prevent its contact with adjacent sensitive materials.

There is a risk of mould growth when monthly mean surface relative humidities are above a critical relative humidity, $\varphi_{si,cr}$, which should be taken as 0,8 unless more specific information is available from National Regulations or elsewhere.

5.2 Determining parameters

Besides the external climate (air temperature and humidity), three parameters govern surface condensation and mould growth:

a) the "thermal quality" of each building envelope element, represented by thermal resistance, thermal bridges, geometry and internal surface resistance. The thermal quality can be characterized by the temperature factor at the internal surface, f_{Rsi};

NOTE ISO 10211 gives a method for calculating weighting factors, when there is more than one inside boundary temperature.

b) the internal moisture supply;

c) internal air temperature and the heating system and its settings.

5.3 Design for avoidance of mould growth, corrosion or other moisture damage

To avoid mould growth the monthly mean relative humidity at the surface should not exceed a critical relative humidity φ_{sicr}, which should be taken as 0,8 unless more specific information is available from National Regulations or elsewhere. Other criteria, e.g. $\varphi_{sicr} \leq 0,6$ to avoid corrosion, can be used if appropriate.

The principal steps in the design procedure are to determine the internal air humidity and then, based on the required relative humidity at the surface, to calculate the acceptable saturation humidity by volume, v_{sat}, or vapour pressure, p_{sat}, at the surface. From this value, a minimum surface temperature and hence a required "thermal quality" of the building envelope (for a given internal air temperature and expressed by f_{Rsi}) is established.

For each month of the year, go through the following steps:

a) define the external temperature in accordance with 4.2.3;

b) define the external humidity in accordance with 4.2.4;

c) define the internal temperature in accordance with national practice;

d) use the procedure defined in 4.3.2 to obtain the internal relative humidity;

