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Fukt- och värmeteknisk funktion hos byggnadsdelar och konstruktioner – Numerisk simulering av fukttransport

Hygrothermal performance of building components and building elements – Assessment of moisture transfer by numerical simulation

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Hygrothermal performance of building components and building elements - Assessment of moisture transfer by numerical simulation

Performance hygrothermique des composants et parois de bâtiments - Evaluation du transfert d'humidité par simulation numérique

Wärme- und feuchtetechnisches Verhalten von Bauteilen und Bauelementen - Bewertung der Feuchteübertragung durch numerische Simulation

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Contents

Page

Foreword

This document (EN 15026:2007) has been prepared by Technical Committee CEN/TC 89 “Thermal performance of buildings and building components”, the secretariat of which is held by SIS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2007, and conflicting national standards shall be withdrawn at the latest by October 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This standard defines the practical application of hygrothermal simulation software used to predict one-dimensional transient heat and moisture transfer in multi-layer building envelope components subjected to non steady climate conditions on either side. In contrast to the steady-state assessment of interstitial condensation by the Glaser method (as described in EN ISO 13788), transient hygrothermal simulation provides more detailed and accurate information on the risk of moisture problems within building components and on the design of remedial treatment. While the Glaser method considers only steady-state conduction of heat and vapour diffusion, the transient models covered in this standard take account of heat and moisture storage, latent heat effects, and liquid and convective transport under realistic boundary and initial conditions. The application of such models has become widely used in building practice in recent years, resulting in a significant improvement in the accuracy and reproducibility of hygrothermal simulation.

The following examples of transient, one-dimensional heat and moisture phenomena in building components can be simulated by the models covered by this standard:

- drying of initial construction moisture;
- moisture accumulation by interstitial condensation due to diffusion in winter;
- moisture penetration due to driving rain exposure;
- summer condensation due to migration of moisture from outside to inside;
- exterior surface condensation due to cooling by longwave radiation exchange;
- moisture-related heat losses by transmission and moisture evaporation.

The factors relevant to hygrothermal building component simulation are summarised below. The standard starts with the description of the physical model on which hygrothermal simulation tools are based. Then the necessary input parameters and their procurement are dealt with. A benchmark case with an analytical solution is given for the assessment of numerical simulation tools. The evaluation, interpretation and documentation of the output form the last part.

Inputs

- Assembly, orientation and inclination of building components
- Hygrothermal material parameters and functions
- Boundary conditions, surface transfer for internal and external climate
- Initial condition, calculation period, numerical control parameters

Outputs

- Temperature and heat flux distributions and temporal variations
- Water content, relative humidity and moisture flux distributions and temporal variations

Post processing

- Energy use, economy & ecology
- Biological growth, rot and corrosion
- Moisture related damage and degradation

The post processing tools are not part of this standard. As far as possible references to publications dealing with these tools is given.

1 Scope

This standard specifies the equations to be used in a simulation method for calculating the non steady transfer of heat and moisture through building structures.

It also provides a benchmark example intended to be used for validating a simulation method claiming conformity with this standard, together with the allowed tolerances.

The equations in this standard take account of the following storage and one-dimensional transport phenomena:

- heat storage in dry building materials and absorbed water;
- heat transport by moisture-dependent thermal conduction;
- latent heat transfer by vapour diffusion;
- moisture storage by vapour sorption and capillary forces;
- moisture transport by vapour diffusion;
- moisture transport by liquid transport (surface diffusion and capillary flow).

The equations described in this standard account for the following climatic variables:

- internal and external temperature;
- internal and external humidity;
- solar and longwave radiation;
- precipitation (normal and driving rain);
- wind speed and direction.

The hygrothermal equations described in this standard shall not be applied in cases where:

- convection takes place through holes and cracks;
- two-dimensional effects play an important part (e.g. rising damp, conditions around thermal bridges, effect of gravitational forces);
- hydraulic, osmotic, electrophoretic forces are present;
- daily mean temperatures in the component exceed 50 °C.

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.

EN 12664, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Dry and moist products of medium and low thermal resistance*

EN 12667, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Products of high and medium thermal resistance*

EN 12939, *Thermal performance of building materials and products — Determination of thermal resistance by means of guarded hot plate and heat flow meter methods — Thick products of high and medium thermal resistance*

EN ISO 7345, *Thermal insulation – Physical quantities and definitions (ISO 7345:1987)*

prEN ISO 9346:2005, *Hygrothermal performance of buildings and building materials - Mass transfer - Physical quantities and definitions (ISO/DIS 9346:2005)*

prEN ISO 10456, *Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO/DIS 10456:2005)*

EN ISO 12571, *Hygrothermal performance of building materials and products – Determination of hygroscopic sorption properties (ISO 12571:2000)*

EN ISO 12572, *Hygrothermal performance of building materials and products – Determination of water vapour transmission properties (ISO 12572:2001)*

prEN ISO 15927-3, *Hygrothermal performance of buildings - Calculation and presentation of climatic data - Part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data (ISO/DIS 15927-3:2006)*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in prEN ISO 9346:2005 and EN ISO 7345 apply. Other terms used are defined in the relevant clauses of this standard.

3.2 Symbols and units

Symbol	**Quantity**	**Unit**
c_{m}	specific heat capacity of dry material	J/(kg·K)
c_{w}	specific heat capacity of liquid water	J/(kg·K)
D_{w}	moisture diffusivity	m^2/s
E_{sol}	total flux density of incident solar radiation	$\mathrm{W/m}^2$

g	density of moisture flow rate	kg/(m²·s)
g_p	density of moisture flow rate of available water from precipitation	kg/(m²·s)
g_v	density of water vapour flow rate	kg/(m²·s)
g_w	density of liquid water flow rate	kg/(m²·s)
$g_{w,max}$	density of water flow rate which can be absorbed at the surface of a material	kg/(m²·s)
h	surface heat transfer coefficient	W/(m²·K)
h_c	convective heat transfer coefficient	W/(m²·K)
h_e	specific latent enthalpy of evaporation or condensation	J/kg
h_r	radiative heat transfer coefficient	W/(m²·K)
K	liquid conductivity	s/m
p_a	ambient atmospheric pressure	Pa
p_{suc}	suction pressure	Pa
p_v	partial water vapour pressure	Pa
$p_{v,a}$	partial water vapour pressure in the air	Pa
$p_{v,s}$	partial water vapour pressure at a surface	Pa
$p_{v,sat}$	saturated water vapour pressure	Pa
p_w	water pressure inside pores	Pa
q	density of heat flow rate	W/m²
q_{lat}	density of latent heat flow rate	W/m²
q_{sens}	density of sensible heat flow rate	W/m²
R_w	liquid moisture flow resistance of interface	m/s
R_{H2O}	gas constant of water vapour	J/(kg·K)
$s_{d,s}$	equivalent vapour diffusion thickness of a surface layer	m
T	thermodynamic temperature	K
T_a	air temperature of the surrounding environment	K
T_{eq}	equivalent temperature of the surrounding environment	K

T_r	mean radiant temperature of the surrounding environment	K
T_{surf}	surface temperature	K
t	time	s
v	wind speed	m/s
w	moisture content	kg/m^3
x	distance	m
α_{sol}	solar absorptance	-
δ_0	vapour permeability of still air	kg/(m·s·Pa)
δ_p	vapour permeability of material	kg/(m·s·Pa)
ε	longwave emissivity of the external surface	-
λ	thermal conductivity	W/(m·K)
φ	relative humidity	-
μ	diffusion resistance factor	-
ρ_a	density of air	kg/m^3
ρ_m	density of solid matrix	kg/m^3
ρ_w	density of liquid water	kg/m^3
σ_s	Stefan-Boltzmann constant	W/(m^2·K^4)

4 Hygrothermal equations and material properties

4.1 Assumptions

The hygrothermal equations specified in the following clauses contain the following assumptions:

- constant geometry, no swelling and shrinkage;
- no chemical reactions are occurring;
- latent heat of sorption is equal to latent heat of condensation/evaporation;
- no change in material properties by damage or ageing;
- local equilibrium between liquid and vapour without hysteresis;
- moisture storage function is not dependent on temperature;
- temperature and barometric pressure gradients do not affect vapour diffusion.

The development of the equations is based on the conservation of energy and moisture. The mathematical expression of the conservation laws are the balance equations. The conserved quantity changes in time, only if it is transported between neighbouring control volumes.

Heat conservation shall be expressed by

$$(c_m \cdot \rho_m + c_w \cdot w) \cdot \frac{\partial T}{\partial t} = -\frac{\partial (q_{sens} + q_{lat})}{\partial x} \quad (1)$$

The increase of the moisture content of a control volume shall be determined by the net inflow of moisture. The moisture flow rate equals the sum of the vapour flow rate and the flow rate of liquid water.

$$\frac{\partial w}{\partial t} = -\frac{\partial g}{\partial x} \quad (2)$$

$$g = g_v + g_l \quad (3)$$

The relative humidity shall be defined by the following equation:

$$\varphi = \frac{p_v}{p_{v,sat}(T)} \quad (4)$$

The pressure acting on the water inside a building material due to the capillary forces is different from the pressure of the surrounding air. The difference is called suction.

$$p_{suc} = p_a - p_w \quad (5)$$

The suction of the pore water is related to the relative humidity of the surrounding air by the Kelvin equation:

$$p_{suc} = -\rho_w R_{H2O} T \ln\varphi \quad (6)$$

The relation between the state variables φ, p_v, p_{suc}, T and the moisture content of a building material is defined by the moisture storage function. The moisture storage function of a building material shall be expressed either as the moisture content as a function of suction (suction curve), $w(p_{suc})$, or as the moisture content as a function of the relative humidity (sorption curve), $w(\varphi)$.

4.2 Transport of heat and moisture

4.2.1 Heat transport

4.2.1.1 Heat transport inside materials

Heat transport shall be composed of sensible and latent components. Sensible heat transport shall be calculated with Fourier's law with a thermal conductivity which depends on moisture content.

$$q_{sens} = -\lambda(w) \cdot \frac{\partial T}{\partial x} \quad (7)$$

Latent heat transport shall be calculated by the following equation:

$$q_{lat} = h_e \, g_v \quad (8)$$

4.2.1.2 Heat transport across boundaries

The heat flow from the surrounding environment into the construction consists of convection, shortwave radiation from the sun and longwave radiation exchange with sky and surrounding surfaces.