

Theory of humid air

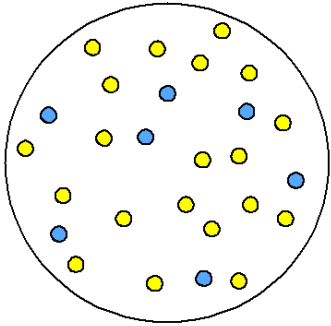
Introduction

A brief overview of the theory of humid air is given in order to better understand the phenomenon of condensation in building constructions.

The following quantities are defined:

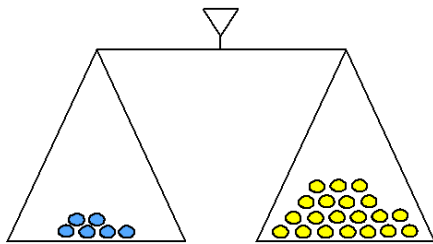
- specific humidity (g/kg)
- absolute air humidity (g/m³)
- vapour pressure (Pa)
- saturation vapour pressure (Pa)
- relative humidity (%)
- dew point (°C)

Specific air humidity and vapour pressure



The air in the outdoors or indoors environment is a mixture of nitrogen (78 %), oxygen (21 %), argon, carbon dioxide and **water vapour**.

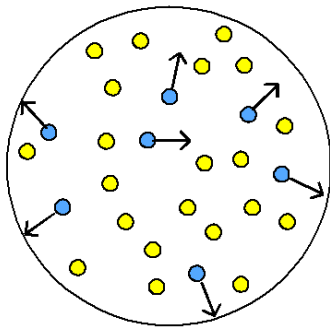
How to quantify the amount of water vapour ?



Method 1

specific air humidity x [g/kg]

= weight of H₂O / weight of dry air



Method 2

vapour pressure p [Pa]

= partial pressure of H₂O molecules

x and p are equivalent quantities (if x is known, also p is).

Water vapour in air

Moist air can be described as an ideal mix of dry air and water vapour

$$\left. \begin{array}{l} \text{vapour} \quad p_v = \rho_v R_v T \\ \text{dry air} \quad p_a = \rho_a R_a T \end{array} \right\} P_g = p_v + p_a \quad (\text{Pa})$$

P_g total gas pressure (Pa)

$$P_g \approx 10^5 \text{ Pa} = 1 \text{ atm}$$

p_a dry air partial pressure (Pa)

$$R_v = 462 \text{ J / Kg.K}$$

p_v vapour partial pressure (Pa)

T absolute temperature (K)

$$R_a = 287 \text{ J / Kg.K}$$

R_j gas constant (J/(Kg.K))

ρ_v vapour concentration = absolute humidity (kg/m³)

$$x = \frac{\rho_v}{\rho_a} \approx 0.62 \cdot \frac{p_v}{P_g - p_v}$$

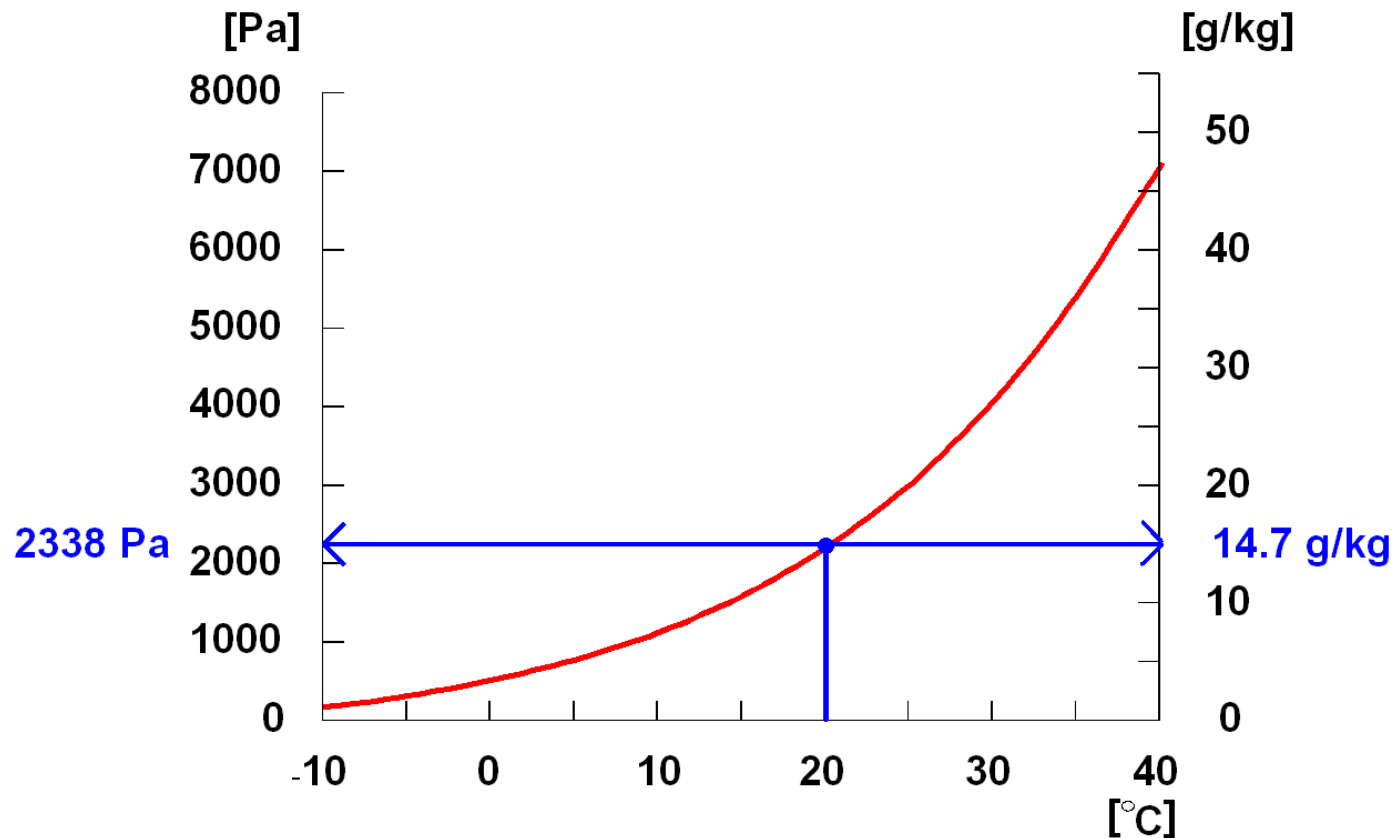
x specific humidity (kg/kg) (*vapour mass/dry air mass*)

Saturation vapour pressure

The amount of vapour in the air is limited, i.e. air can be saturated.

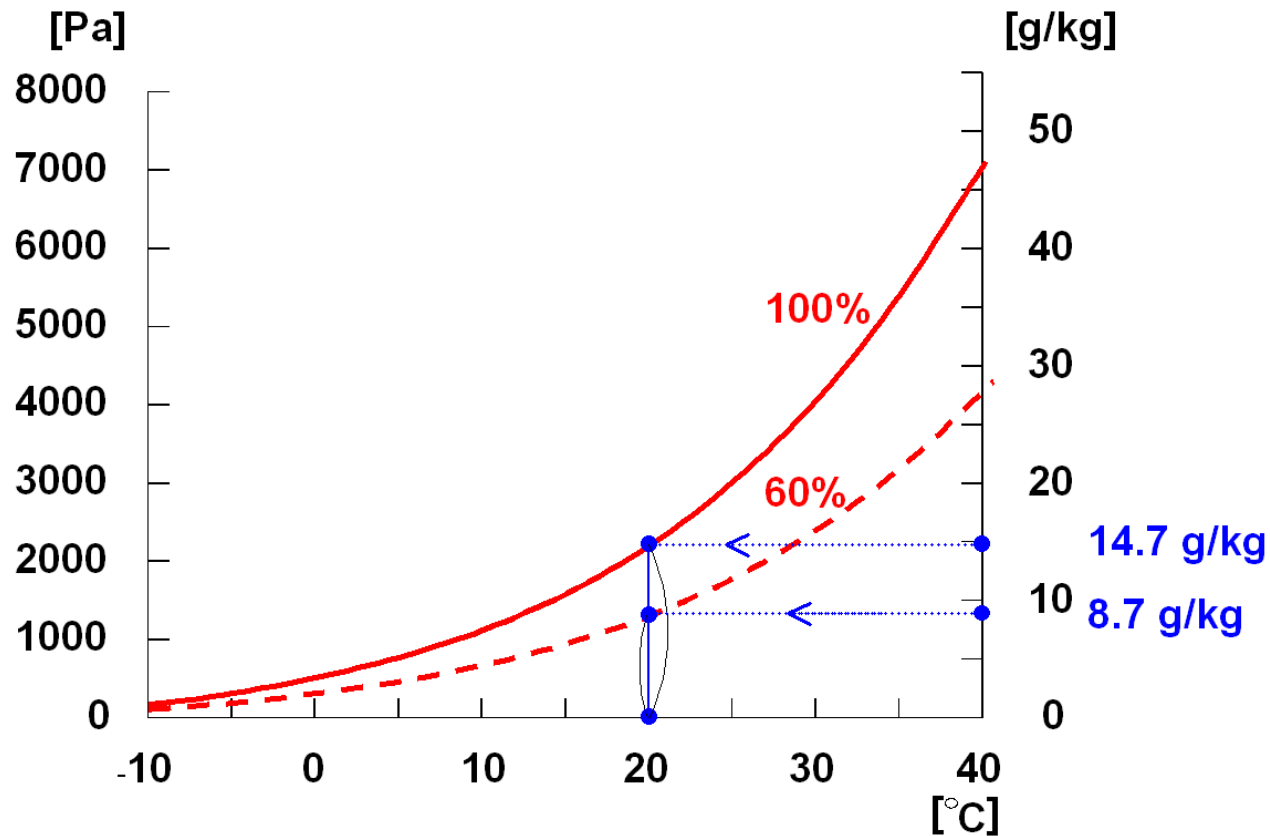
The maximal vapour pressure is called the **saturation vapour pressure p_s** ,

This value of p_s depends on the air temperature.



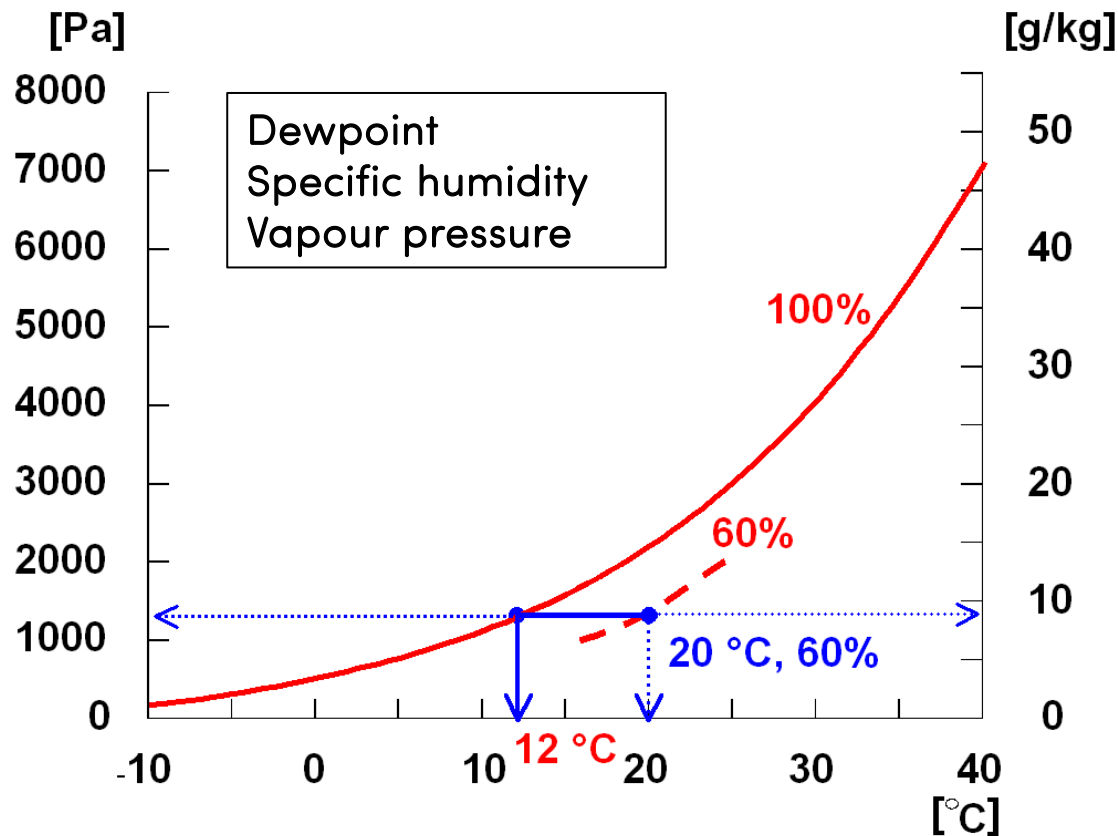
Relative humidity

In a normal environment the amount of vapour is lower than the saturation level. The ratio between the vapour amount present and the saturation amount is called the **relative humidity ϕ** .



Dew point

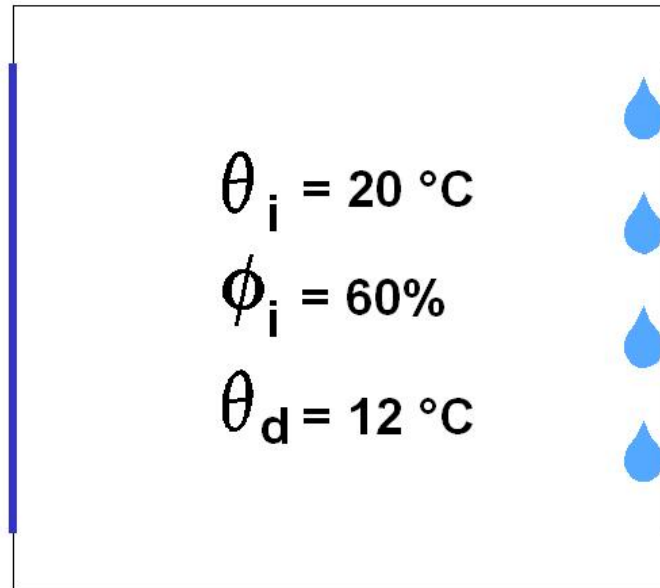
If humid air is cooled without changing its humidity contents, saturation will occur at a certain temperature that is called the **dew point θ_d** .
 θ_d , x and p are equivalent quantities (if one is known, also the others are).



Condensation

Surface **condensation** occurs when the surface temperature is lower than the dew point of the air.

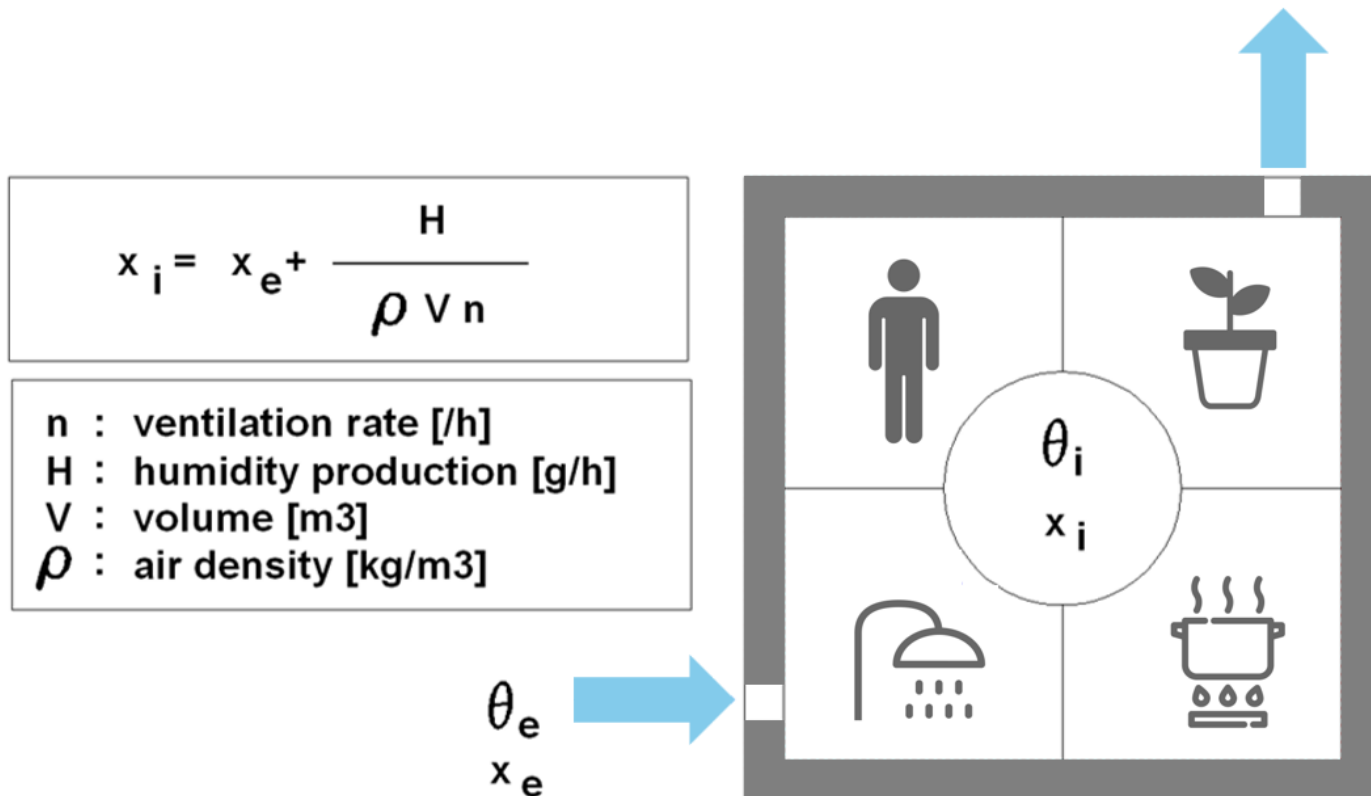
$$\theta_{s1} = 18 \text{ }^\circ\text{C}$$



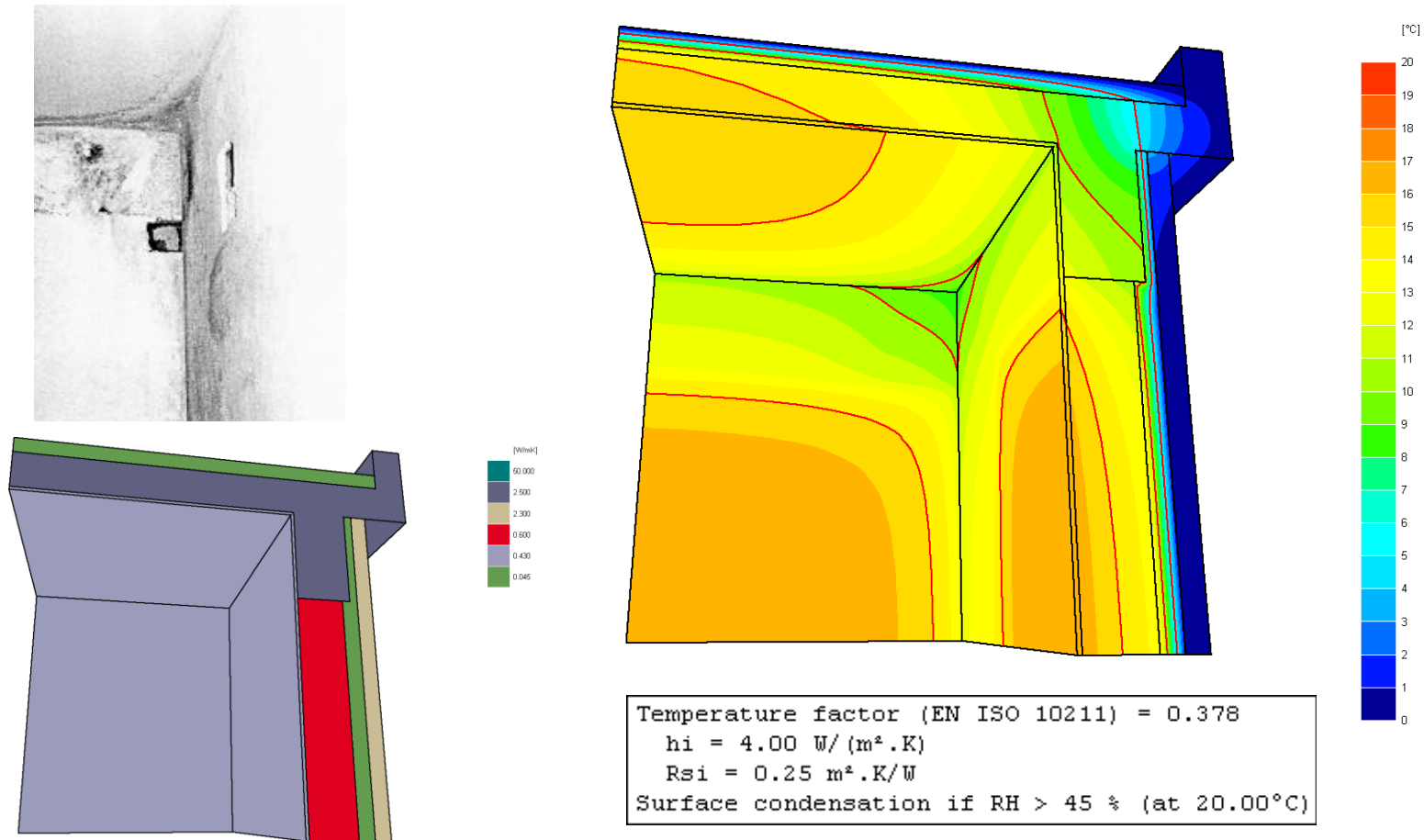
$$\theta_{s2} = 10 \text{ }^\circ\text{C}$$

Air humidity: indoor vs. outdoors

The indoors specific air humidity is normally higher than the outdoors air humidity because of evaporation by people, plants and activities.

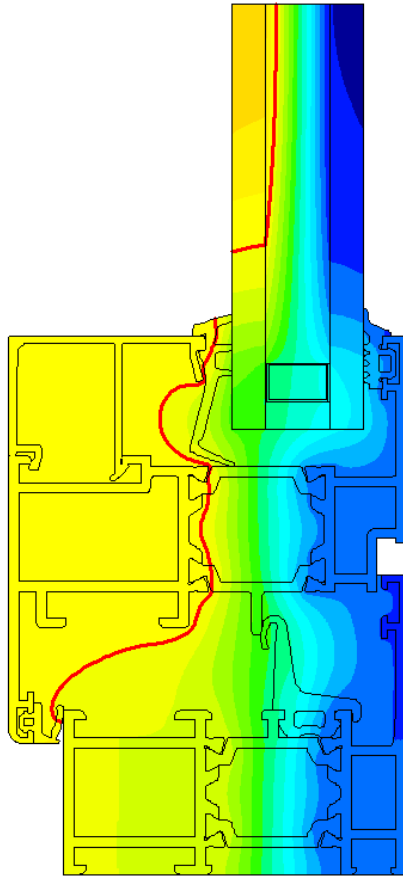
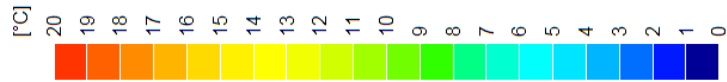


Surface condensation on thermal bridges - example



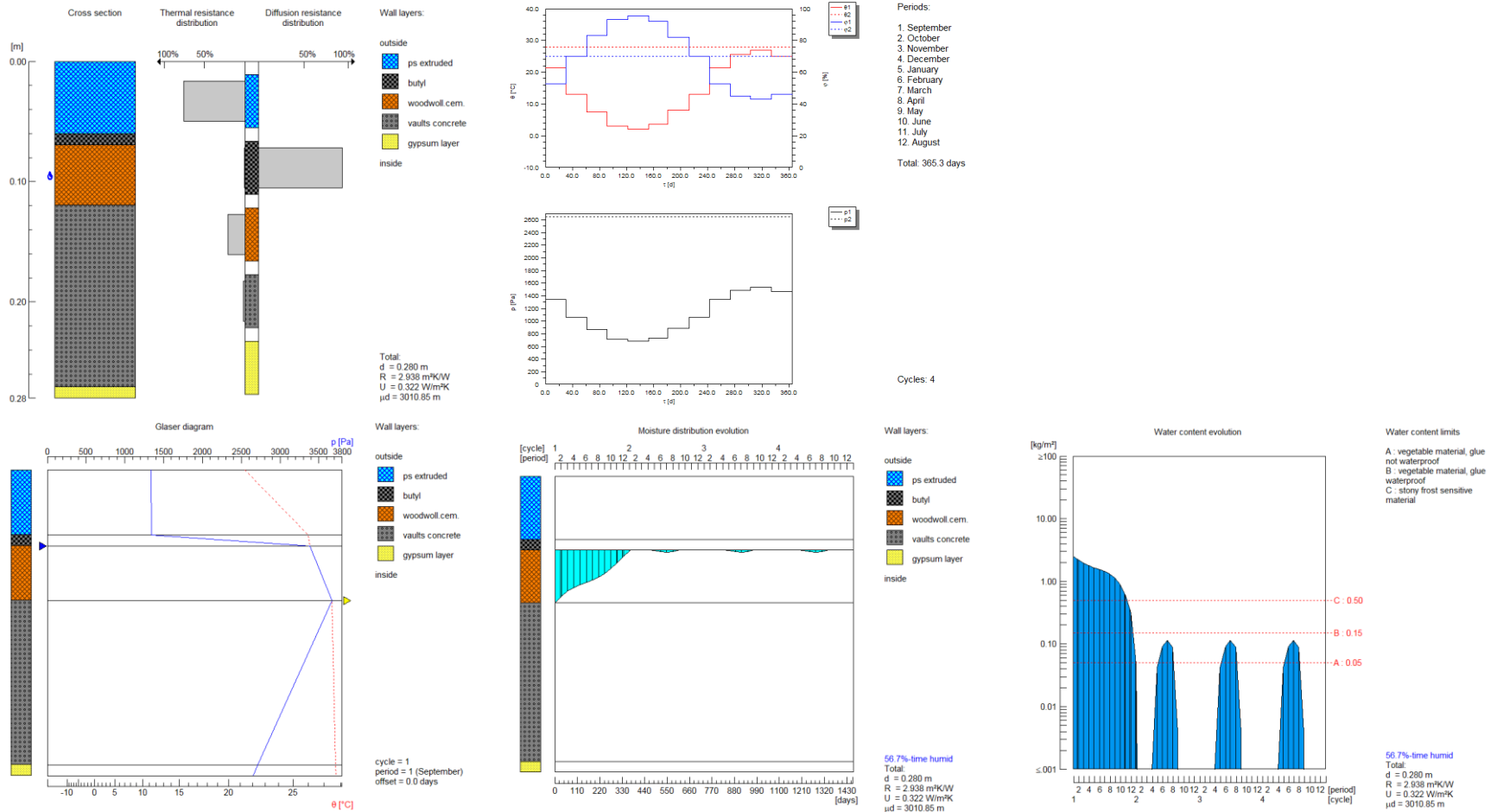
EN ISO 13788 (Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods) for the assessment of mould growth

Surface condensation on window frames and glazing - example



Interstitial condensation - example

The program GLASTA (1D method of Glaser) is demonstrated.
 Glasta project file [GL_EXAMP2.glp](#)



Air humidity calculation online tool

The Physibel online tool: <https://apps.physibel.be/psychrometrics/> allows to derive the humid air properties discussed above.

The validity range temperature is from -30 °C to 100 °C .

Psychrometrics Calculator

Moist Air Properties

Input

Atmospheric Pressure	<input type="text" value="101,325"/>	Pa	▼
Air Temperature	<input type="text" value="20"/>	°C	▼
Relative Humidity	<input type="text" value="50"/>	%	
Dew Point	<input type="text" value="9.27"/>	°C	▼

Output

Saturation Vapour Pressure	2,339.2	Pa
Vapour Pressure	1,169.6	Pa
Specific Humidity	7.26	g/kg
Specific Volume	0.84	m ³ /kg
Density	1.19	kg/m ³

[Visit the documentation](#) to learn more.