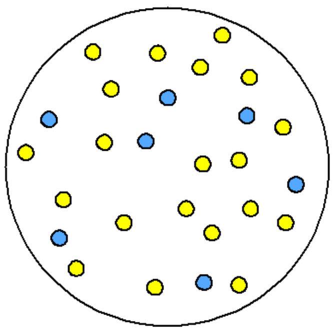
Theory of humid air

Introduction

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

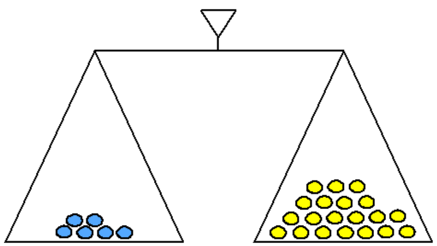
The following quantities are defined:
- absolute air humidity
- vapour pressure
- saturation vapour pressure
- relative humidity
- dew point

Absolute 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.**

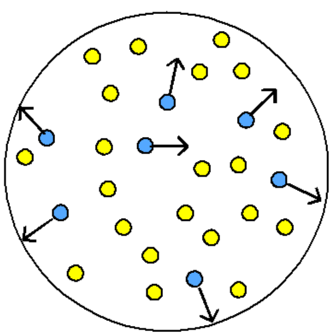
How to quantify the amount of water vapour ?



Method 1

absolute 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

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

P_g	total gas pressure (Pa)
p_a	dry air partial pressure (Pa)
p_v	vapour partial pressure (Pa)
T	absolute temperature (K)
R_j	gas constant (J/(Kg.K))
ρ_v	vapour concentration (kg/m³)

$$P_g \approx 10^5\, Pa = 1\, atm$$

$$R_v = 462\ J/Kg.K$$

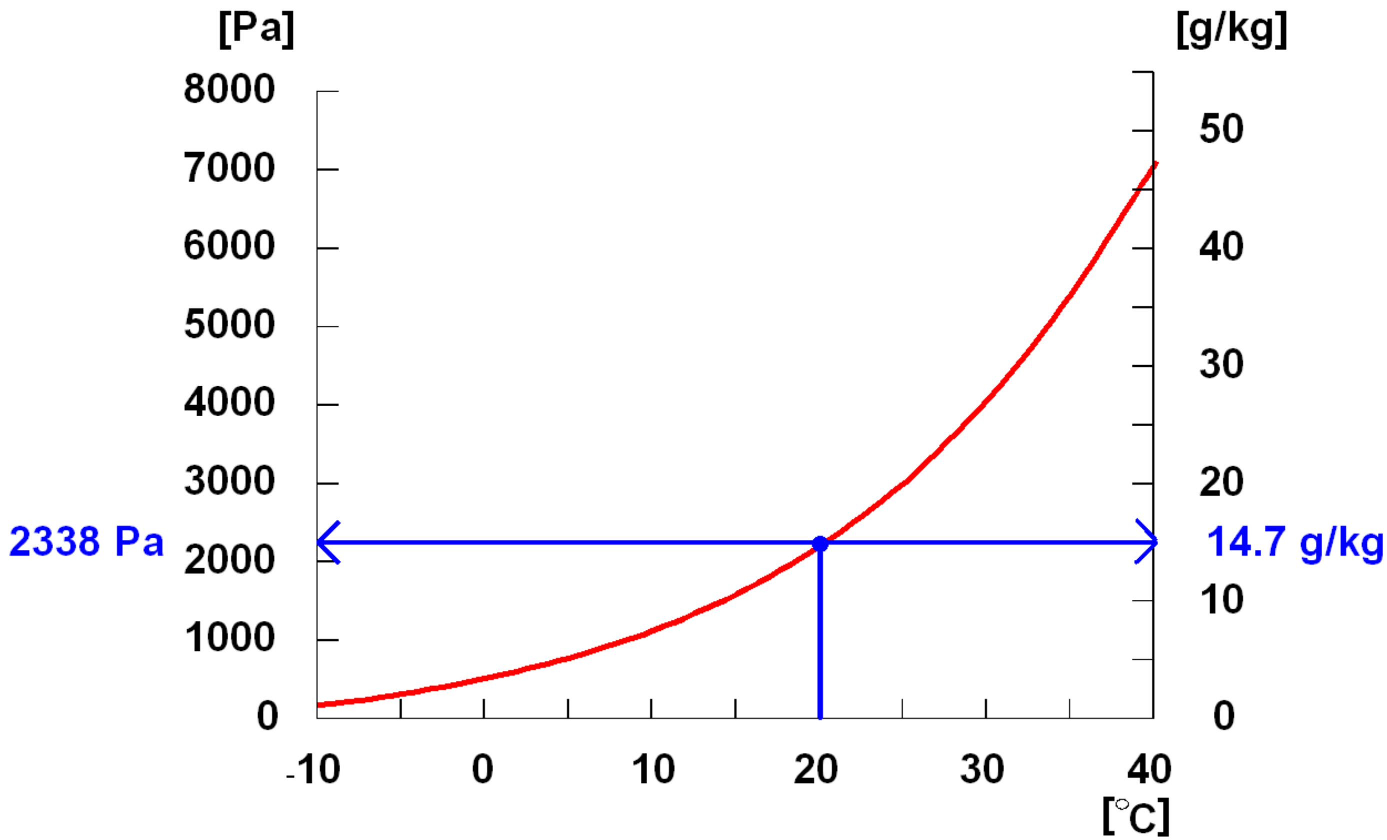
$$R_a = 287\ J/Kg.K$$

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

x absolute air humidity (kg/kg)

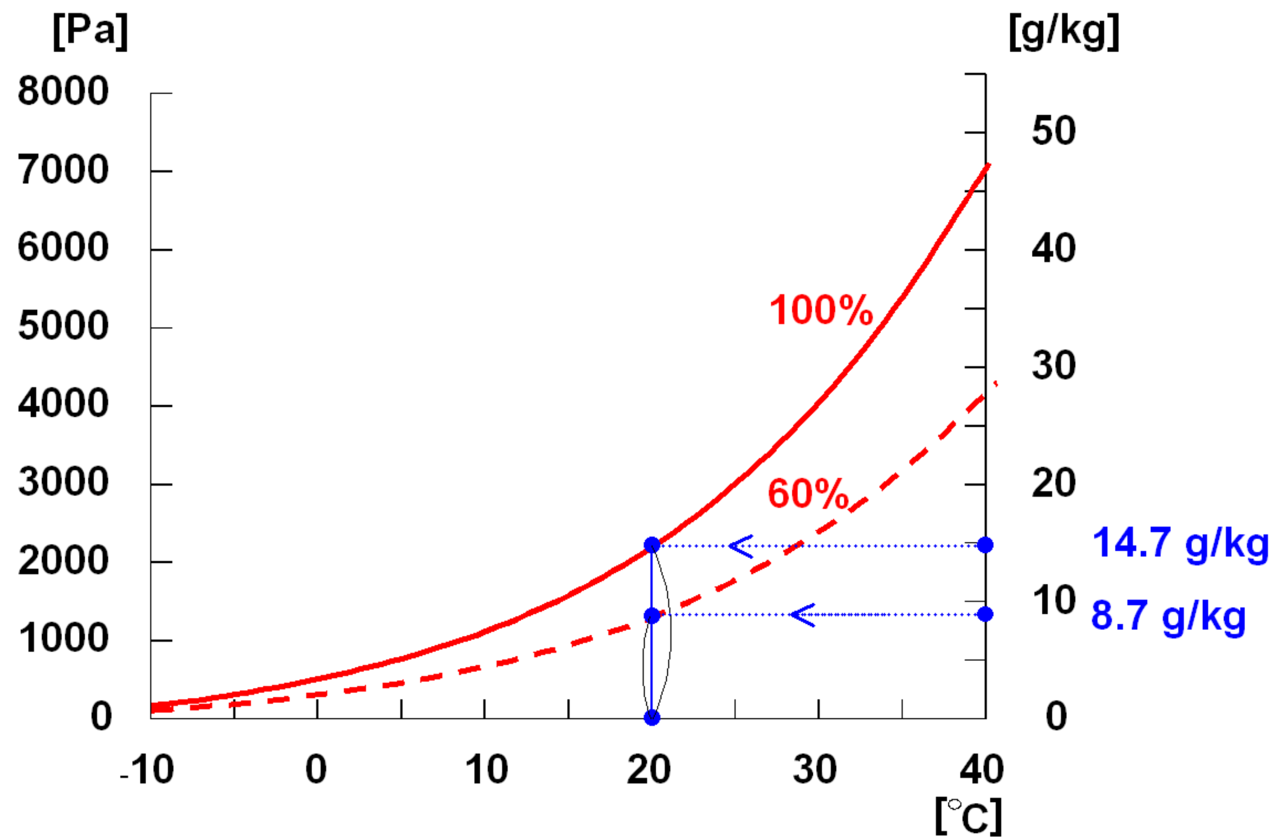
Saturation vapour pressure

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** .



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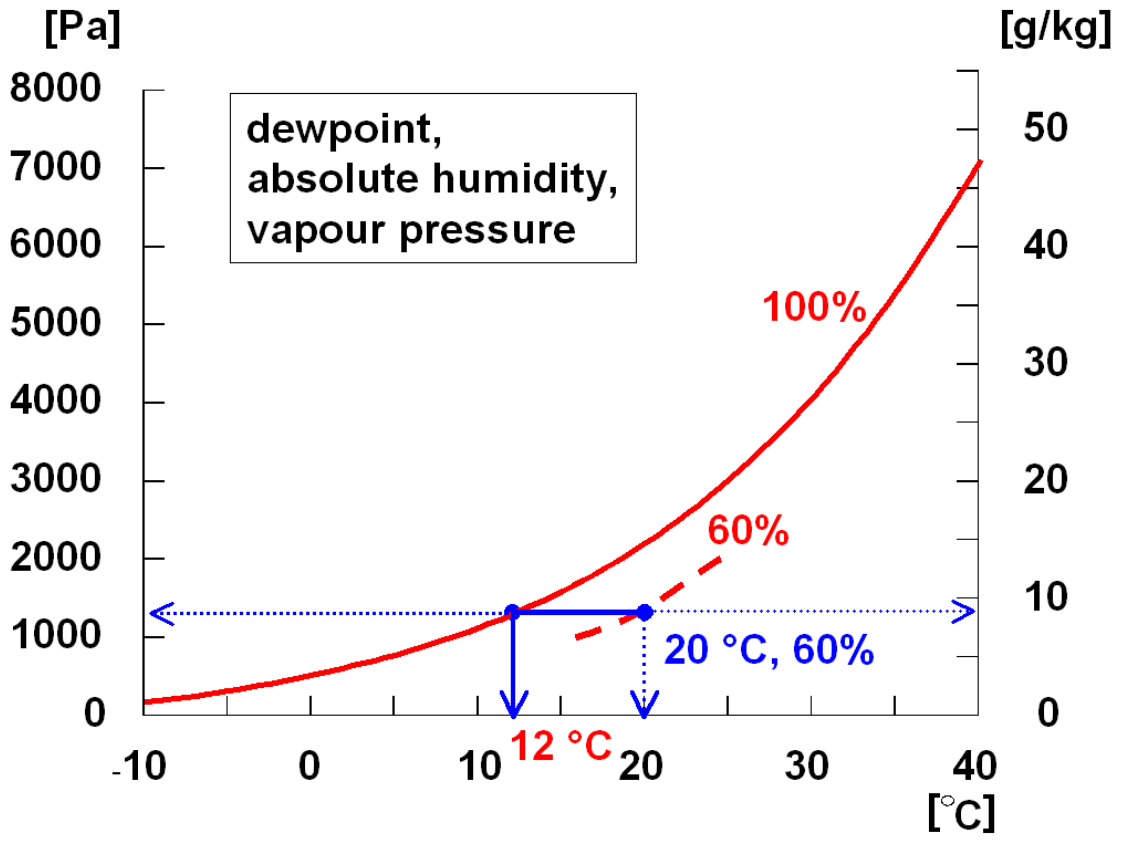
Dew point

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.

$\theta_{s1} = 18\ °C$

$\theta_i = 20\ °C$

$\phi_i = 60\%$

$\theta_d = 12\ °C$

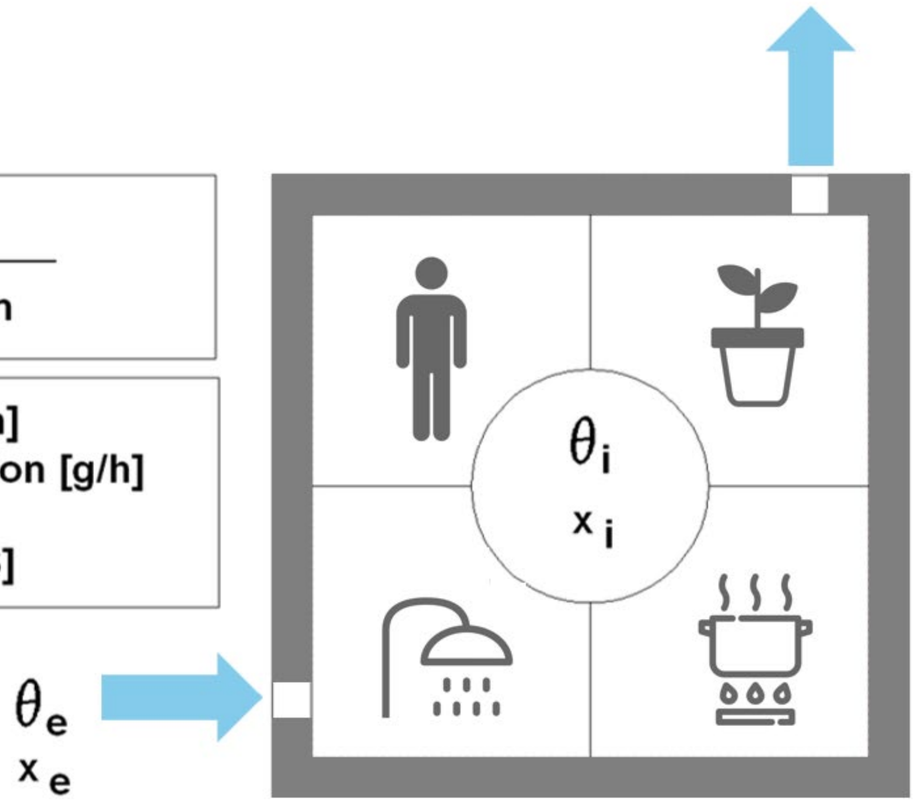
$\theta_{s2} = 10\ °C$

Air humidity: indoor vs. outdoors

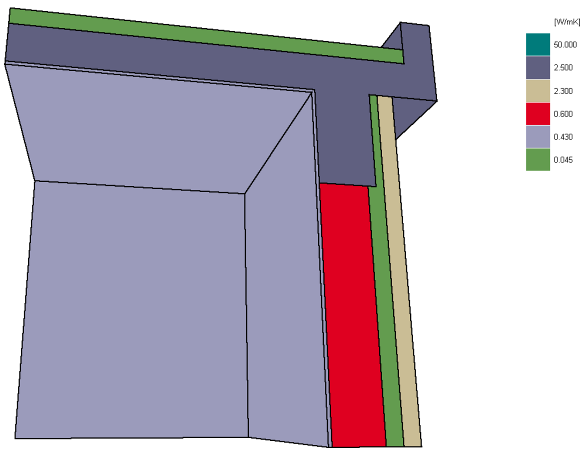
The indoors absolute air humidity is normally higher than the outdoors air humidity because of evaporation by people, plants and activities.

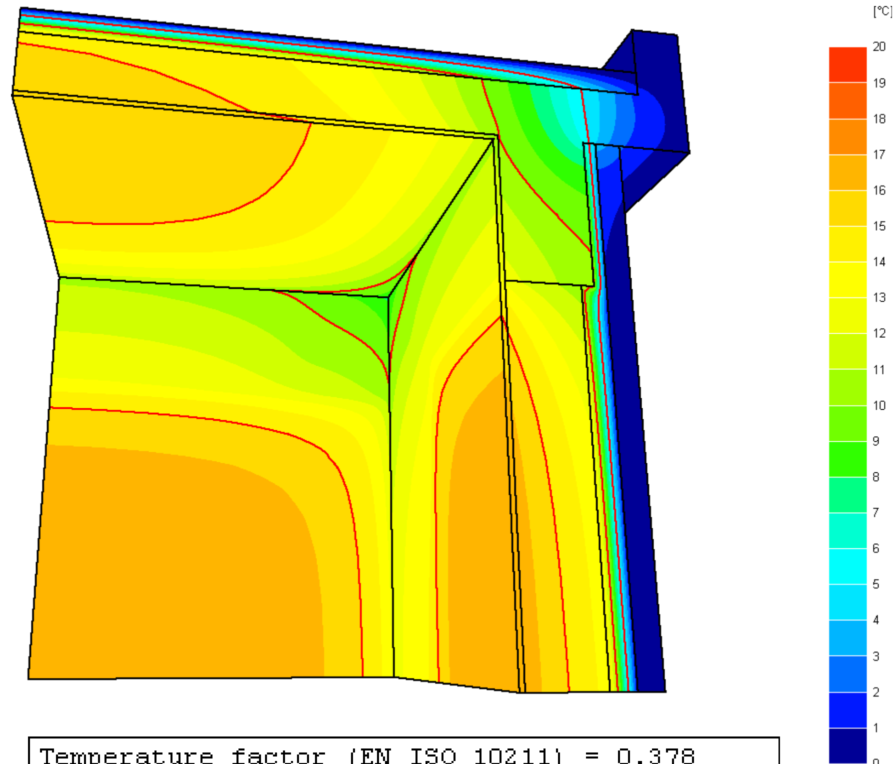
$$x_i = x_e + \frac{H}{\rho \, V \, n}$$

- n : ventilation rate [/h]
- H : humidity production [g/h]
- V : volume [m3]
- ρ : air density [kg/m3]



Surface condensation on thermal bridges - example

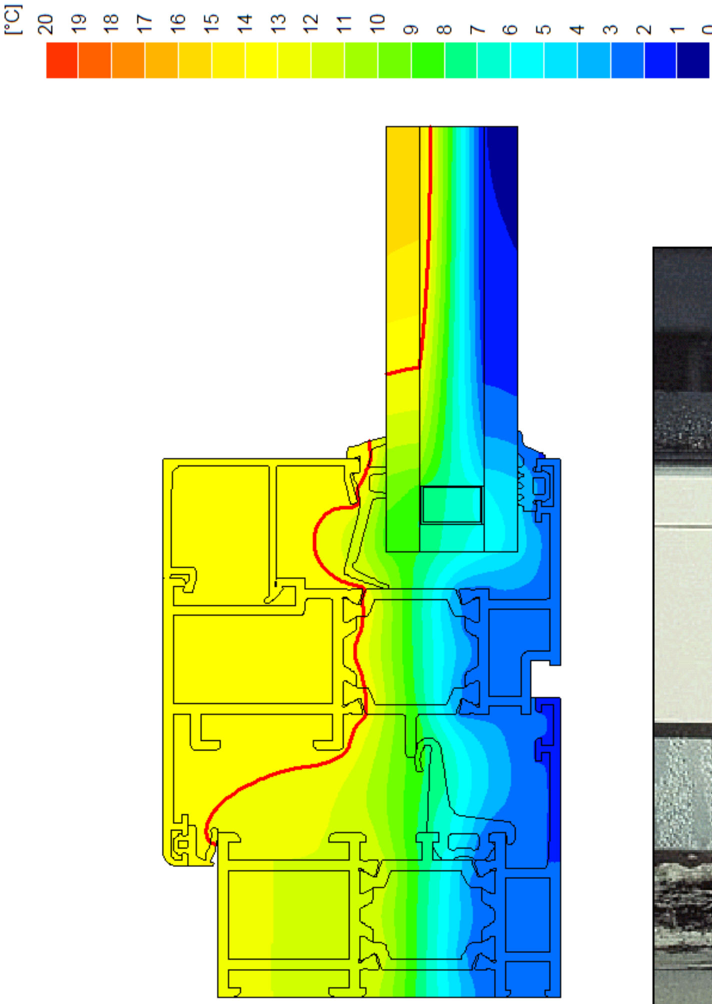




Temperature factor (EN ISO 10211) = 0.378
hi = 4.00 W/(m².K)
Rsi = 0.25 m².K/W
Surface condensation if RH > 45 % (at 20.00°C)

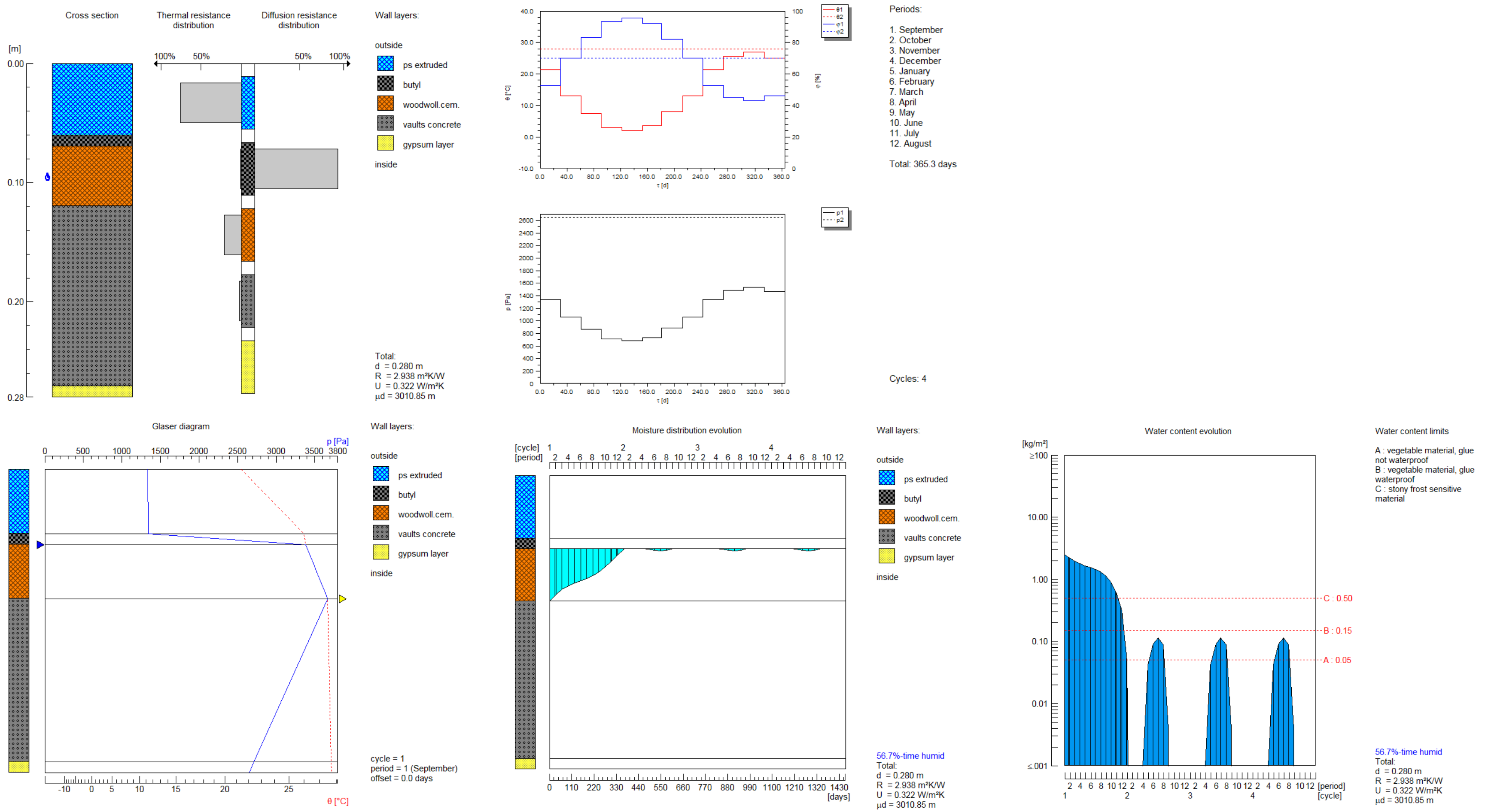
EN ISO 13788 (Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods) for the assessment of mould growth

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	101,325	Pa
Air Temperature	20	°C
Relative Humidity	50	%
Dew Point	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.