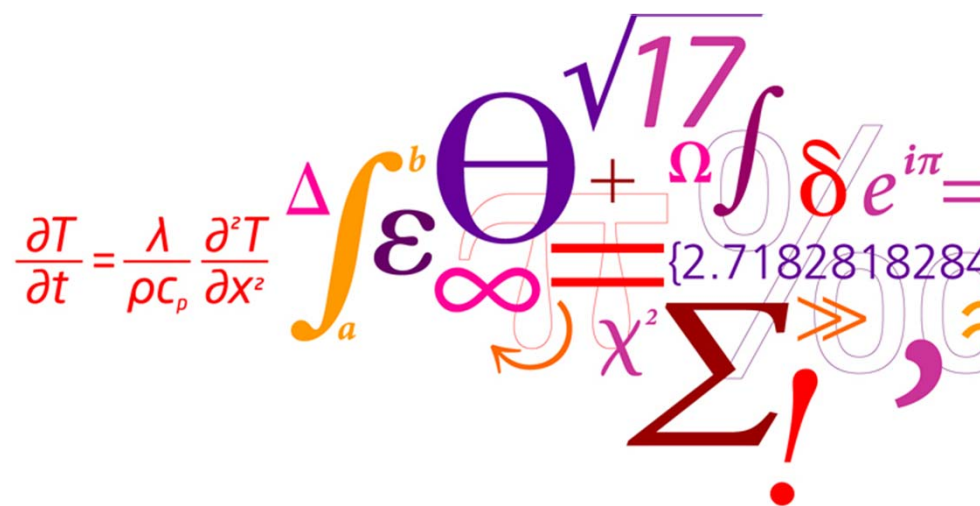


Predicting moisture state of timber members in continuously varying climate

Staffan Svensson, Goran Turk & Tomaz Hozjan



Varying climate alters the safety of timber structures.

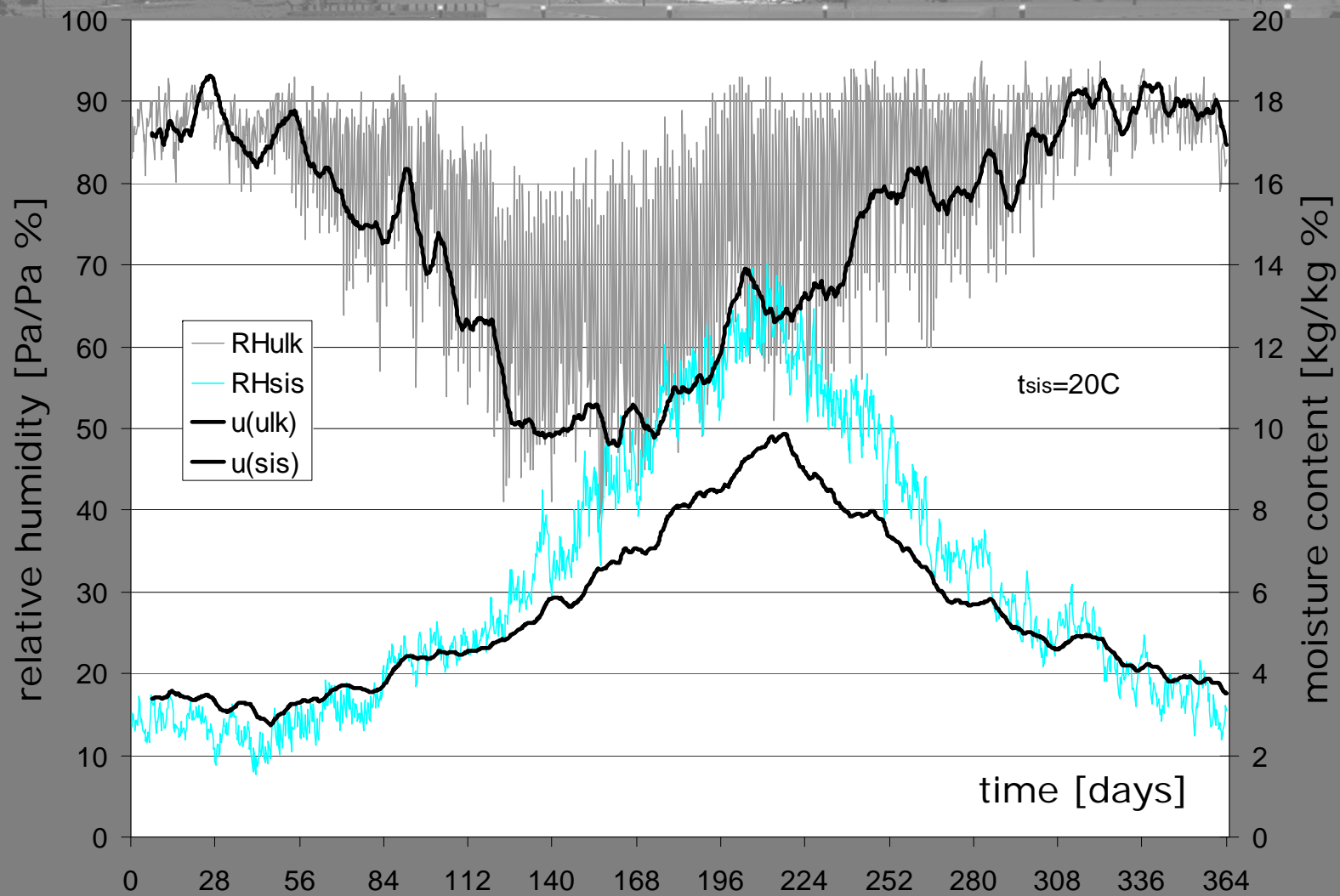
Humidity determines the moisture state of wood.

Moisture in cell wall and cell wall dimension are connected.

Moisture induced stresses are a consequence of constrained dimension change.



Natural climate (humidity) is ever changing

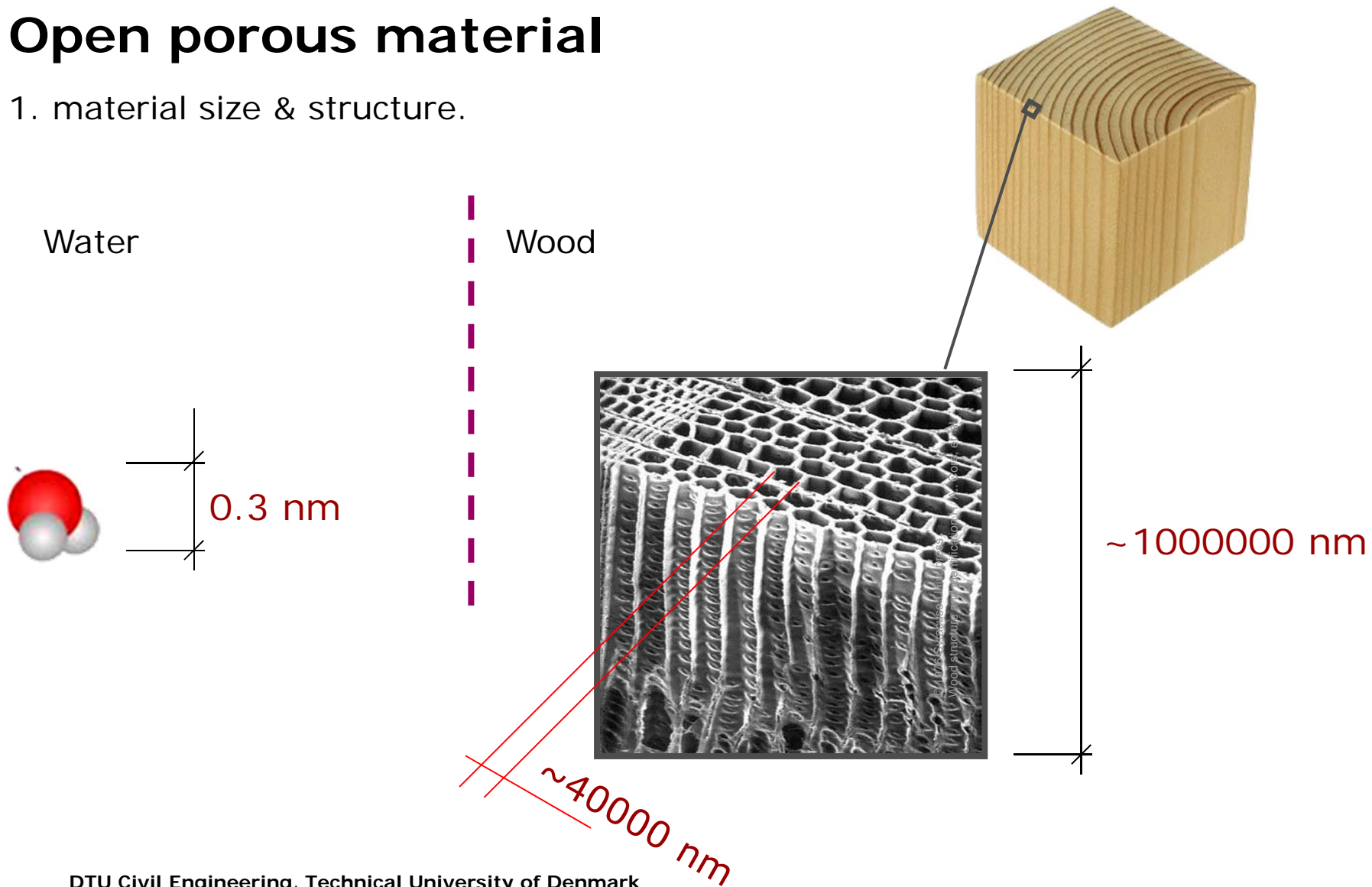


Calculating moisture state of wood

- Wood is a hygroscopic material with an open porous structure. Moisture in wood exists as bound water in the hygroscopic cell wall and as vapor in the pores.
- Sorption is the process of moisture phase change. Equilibrium states between the moisture phases are not one to one relationships, when described with the state parameters wood moisture content and normalized partial vapor pressure (humidity).

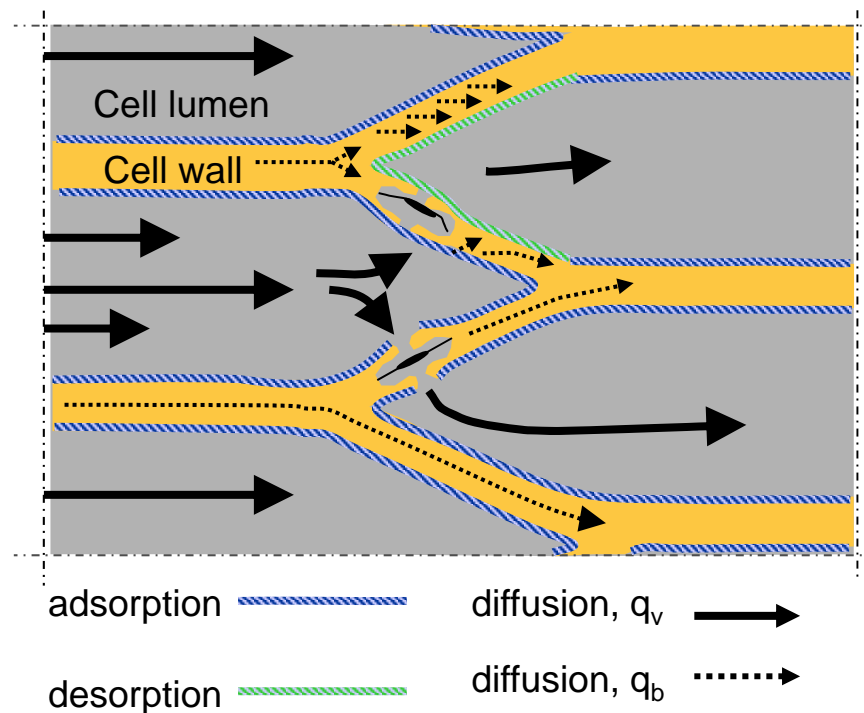
Open porous material

1. material size & structure.



Hygroscopic and open porous material

2. Moisture transport in two phases coupled through sorption



Governing equations

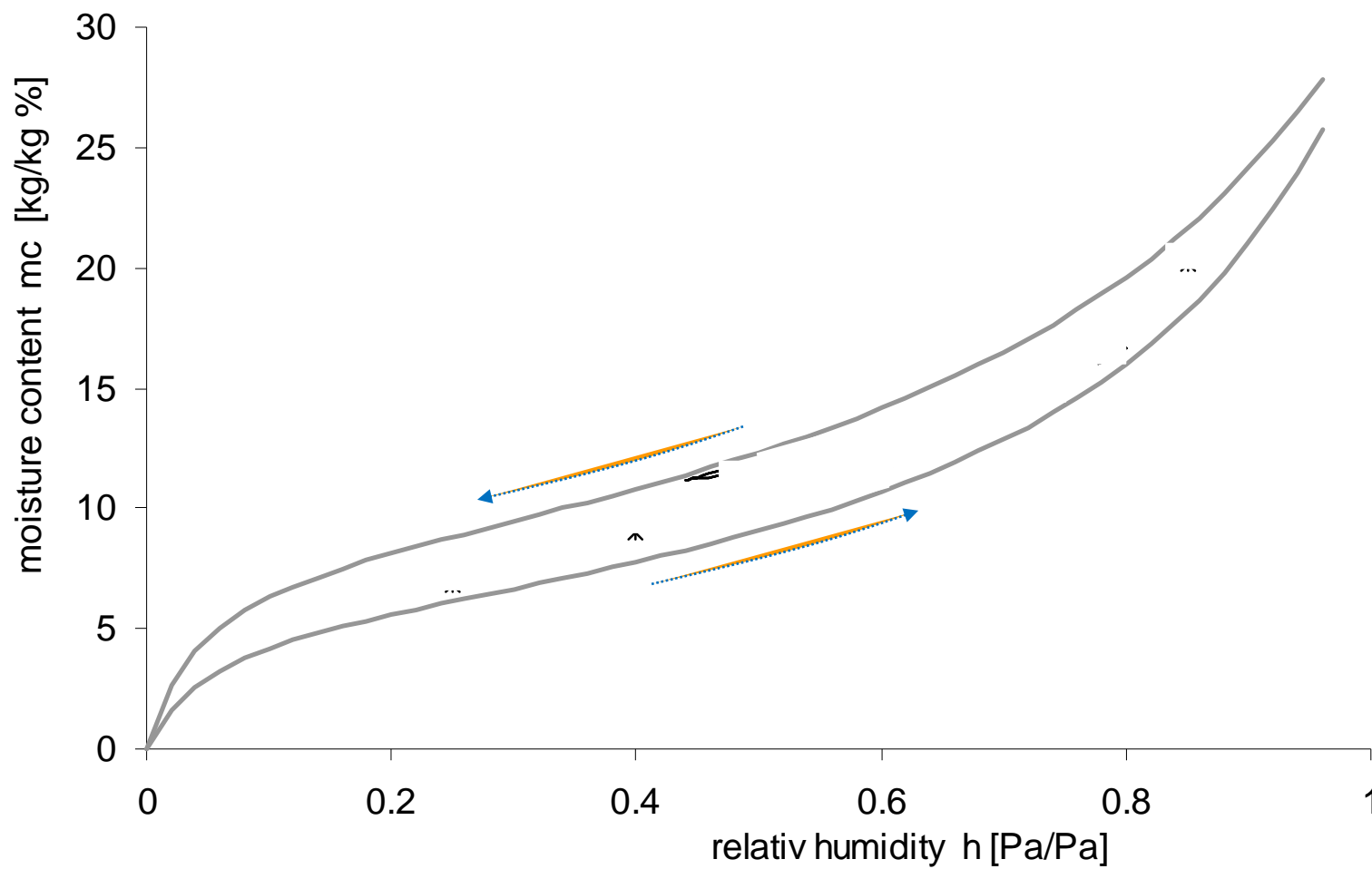
$$\frac{\partial c_v}{\partial t} = \nabla \cdot (\mathcal{D}_v \nabla c_v) + \dot{s}$$

$$\frac{\partial c_b}{\partial t} = \nabla \cdot (\mathcal{D}_b \nabla c_b) + \dot{s}$$

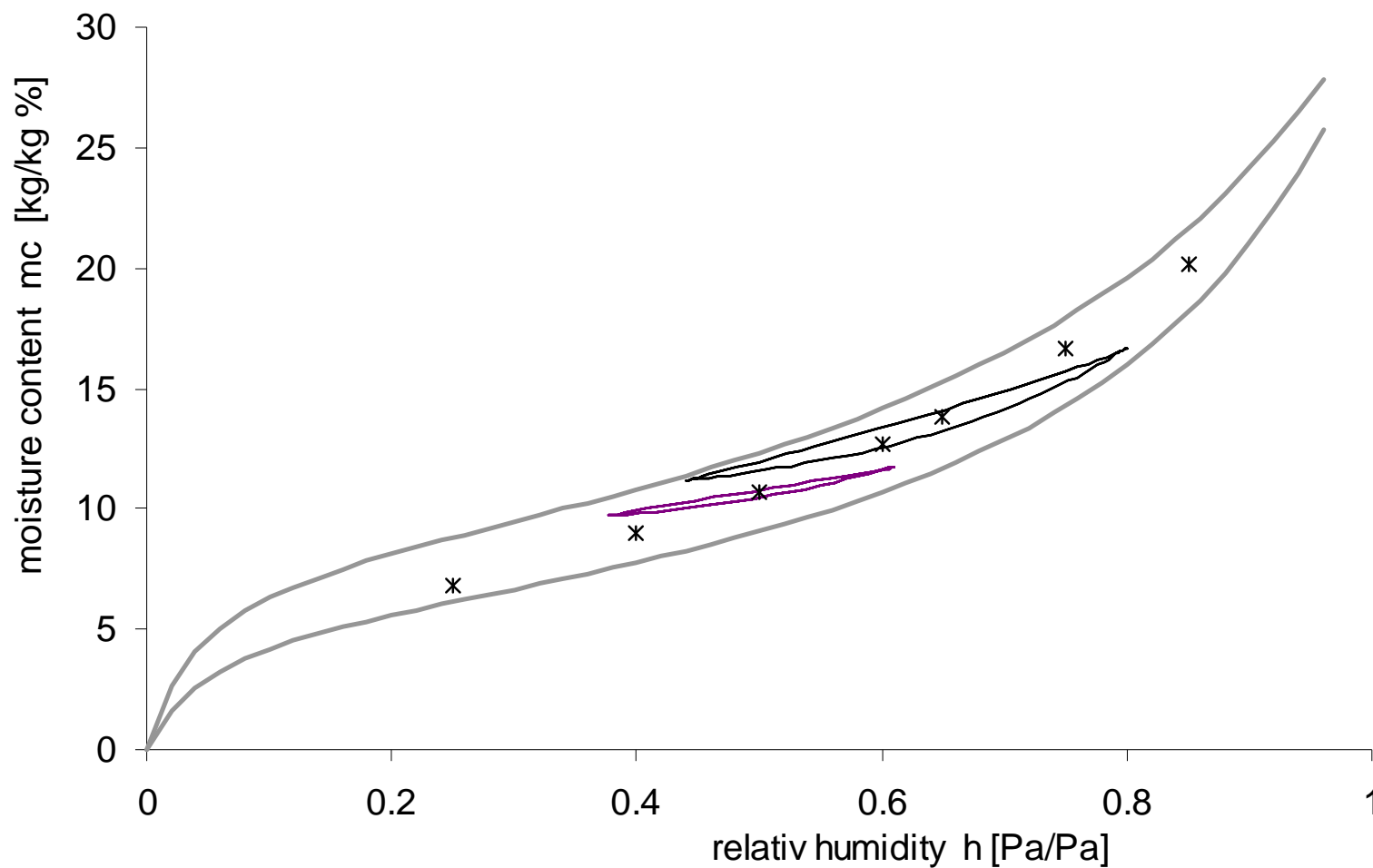
with boundary conditions

$$\begin{cases} \hat{n}_\Gamma q_v = k_{\Gamma} (c_{va} - c_{\Gamma}) ; k_{\Gamma} > 0 \\ c_{\Gamma} = c_{va} ; k_{\Gamma} = 0 \\ \hat{n}_\Gamma q_b = 0 \end{cases}$$

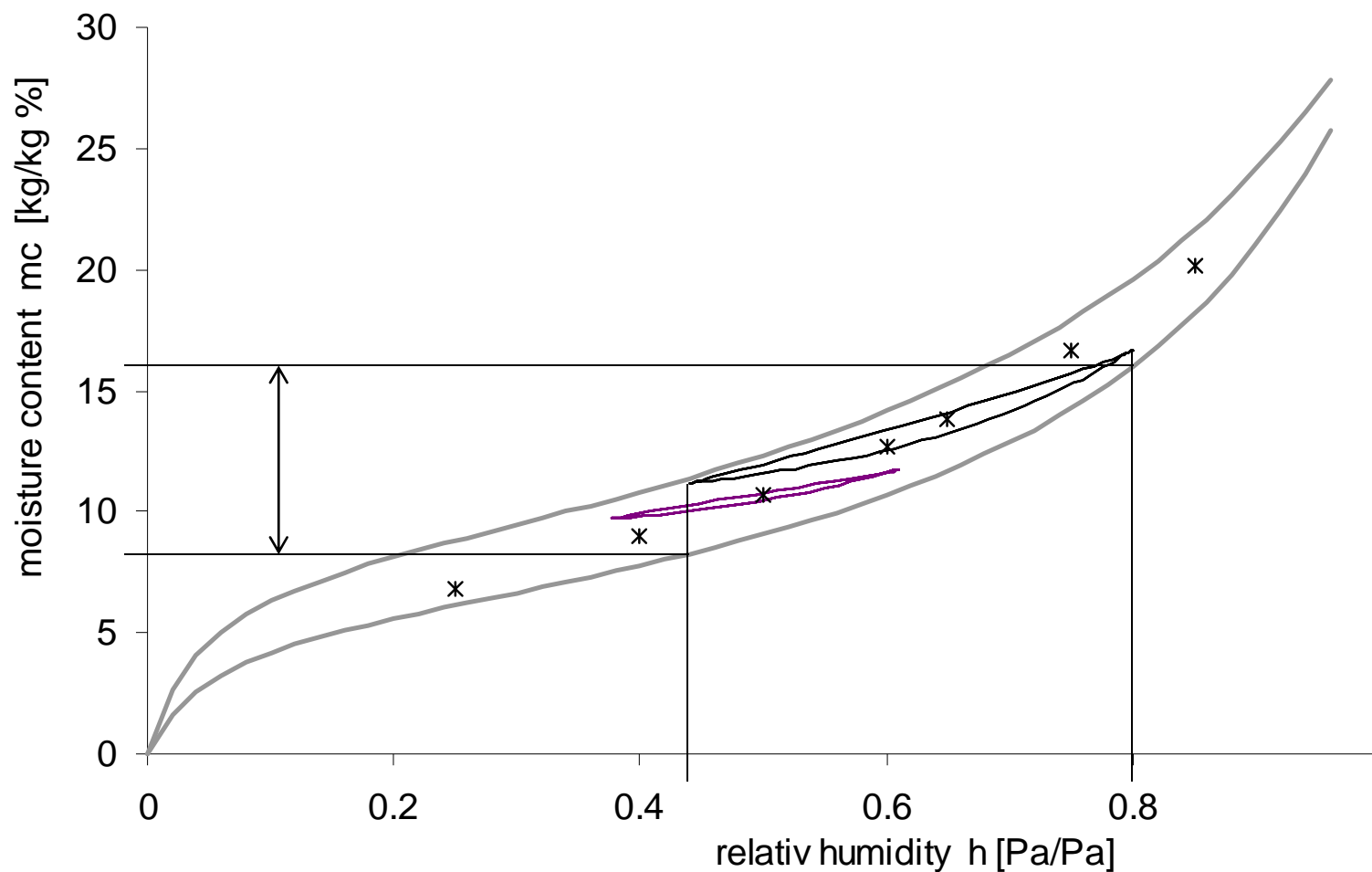
Sorption isotherm, Equilibrium states



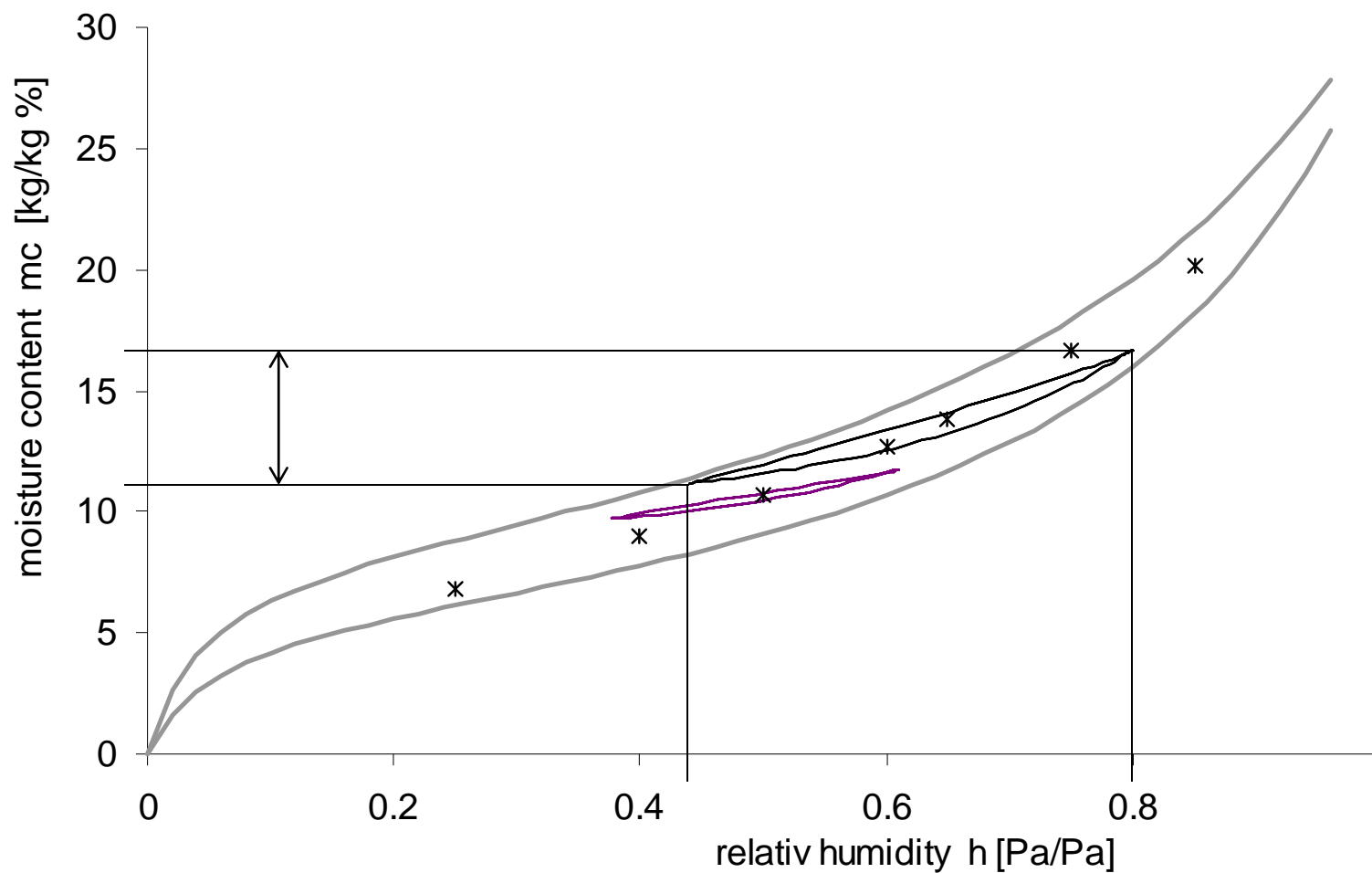
Sorption isotherm, moisture balance hysteresis and the exploited sorption site model



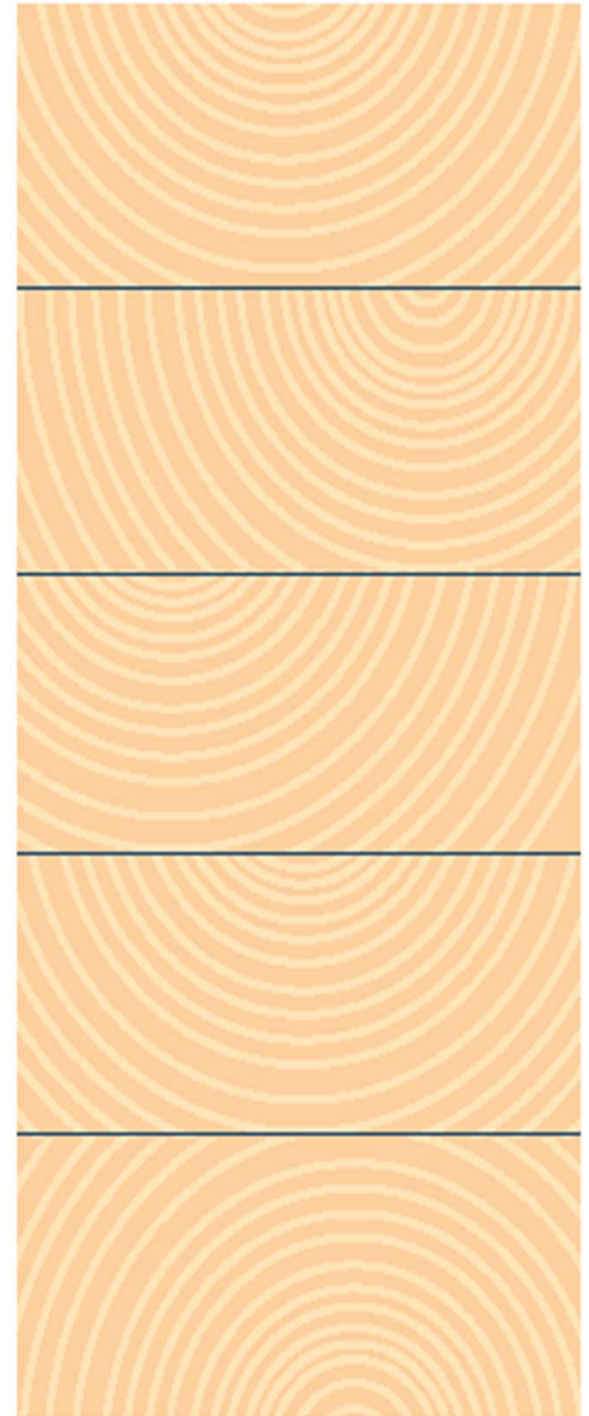
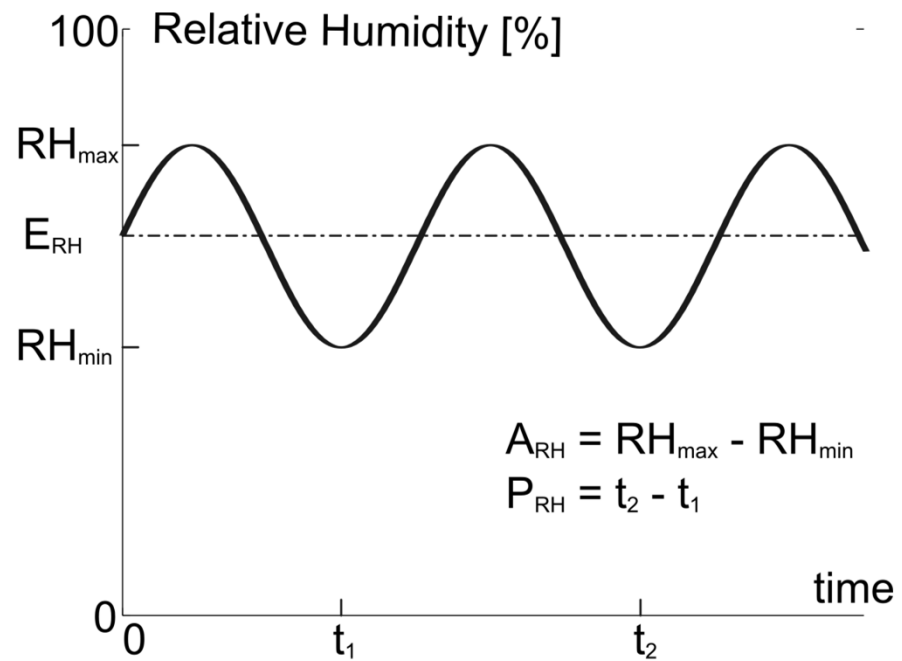
Sorption isotherm, moisture balance hysteresis and the exploited sorption site model



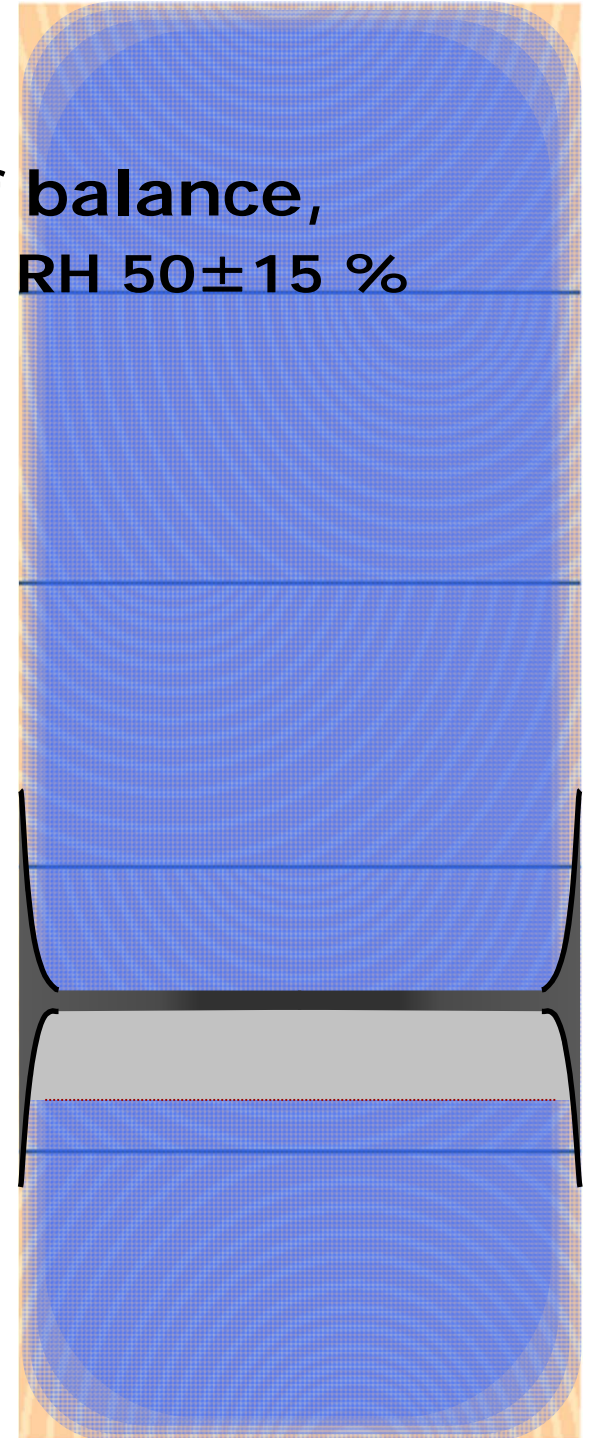
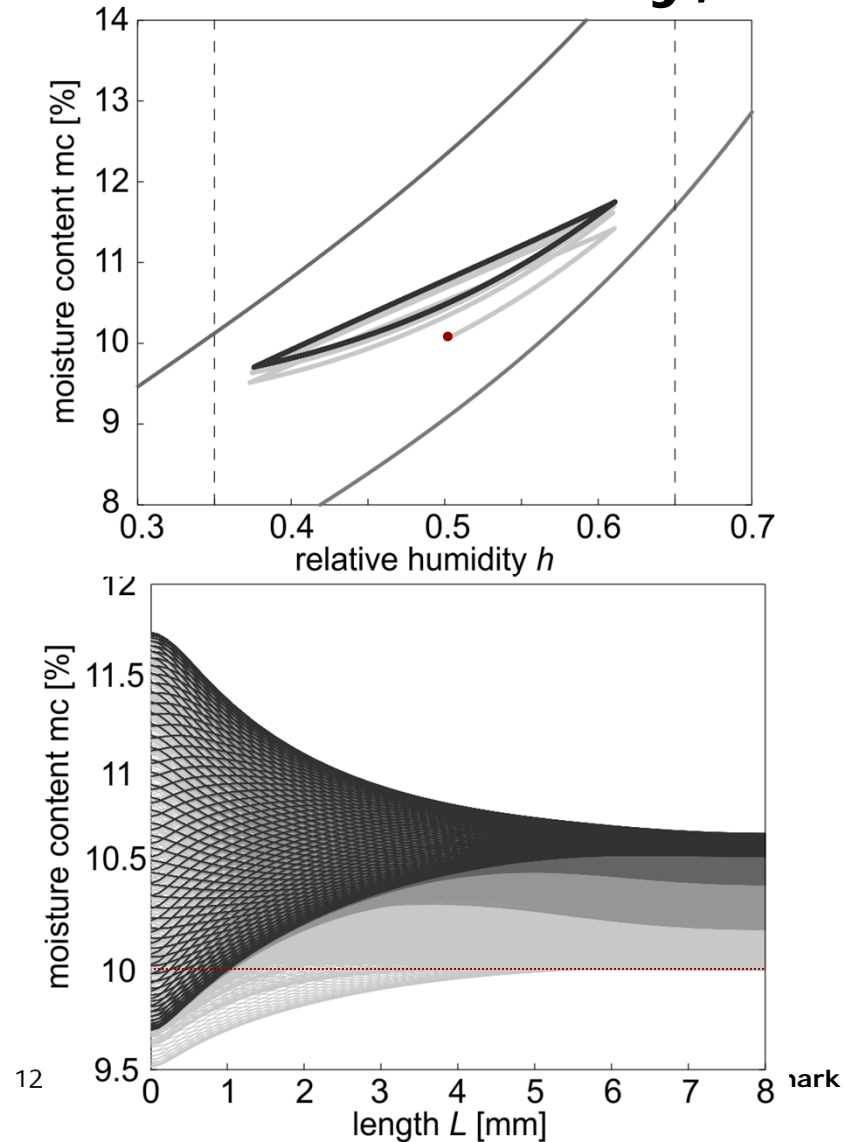
Sorption isotherm, moisture balance hysteresis and the exploited sorption site model



Numerical calculations harmonic humidity

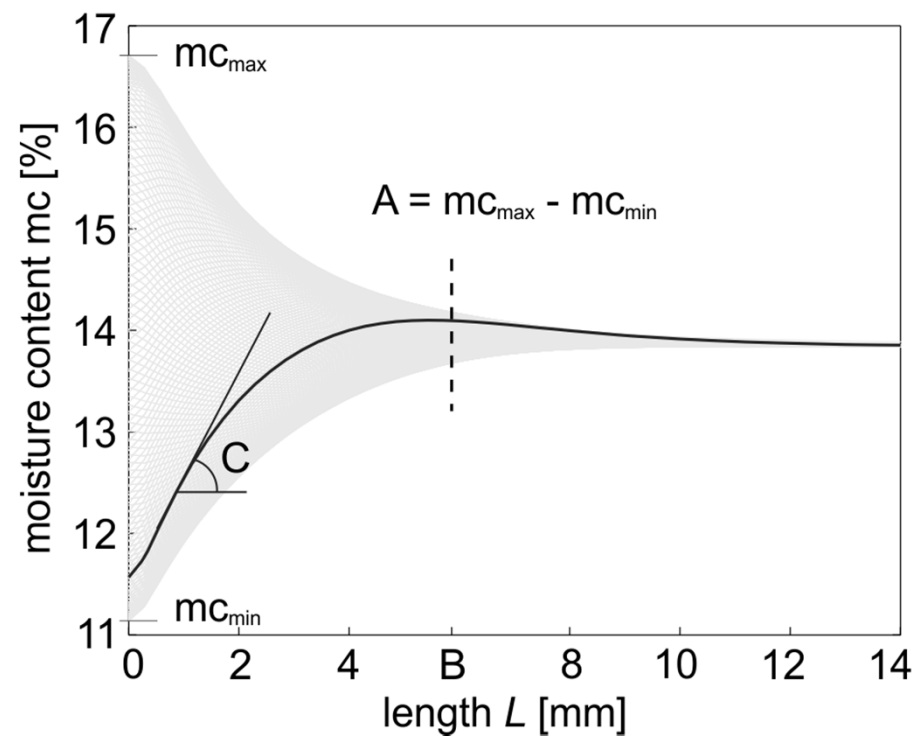
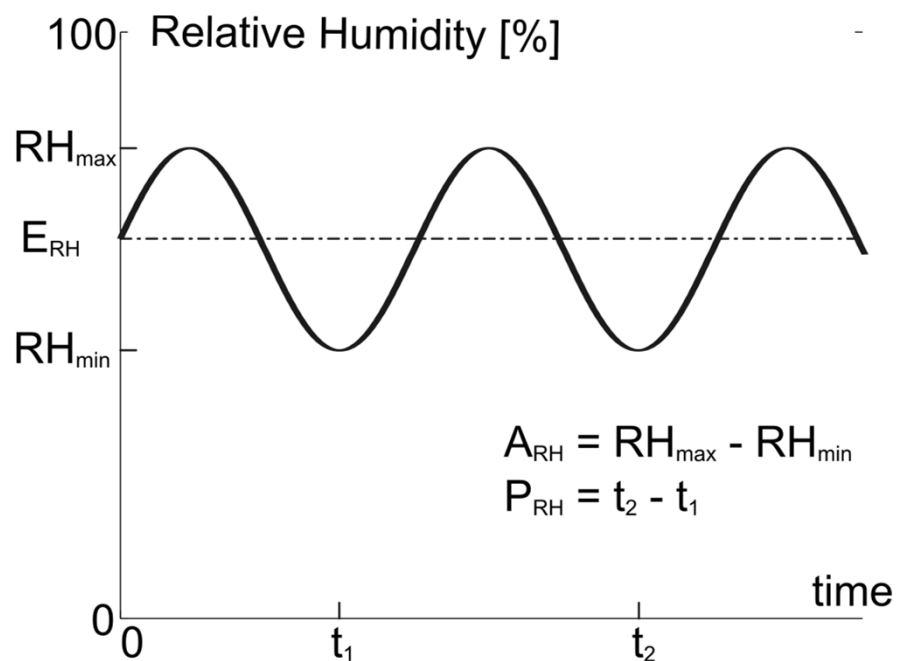


Numerical calculations moisture states for initially out of balance, harmonic humidity, daily period and RH $50 \pm 15\%$



Numerical calculations

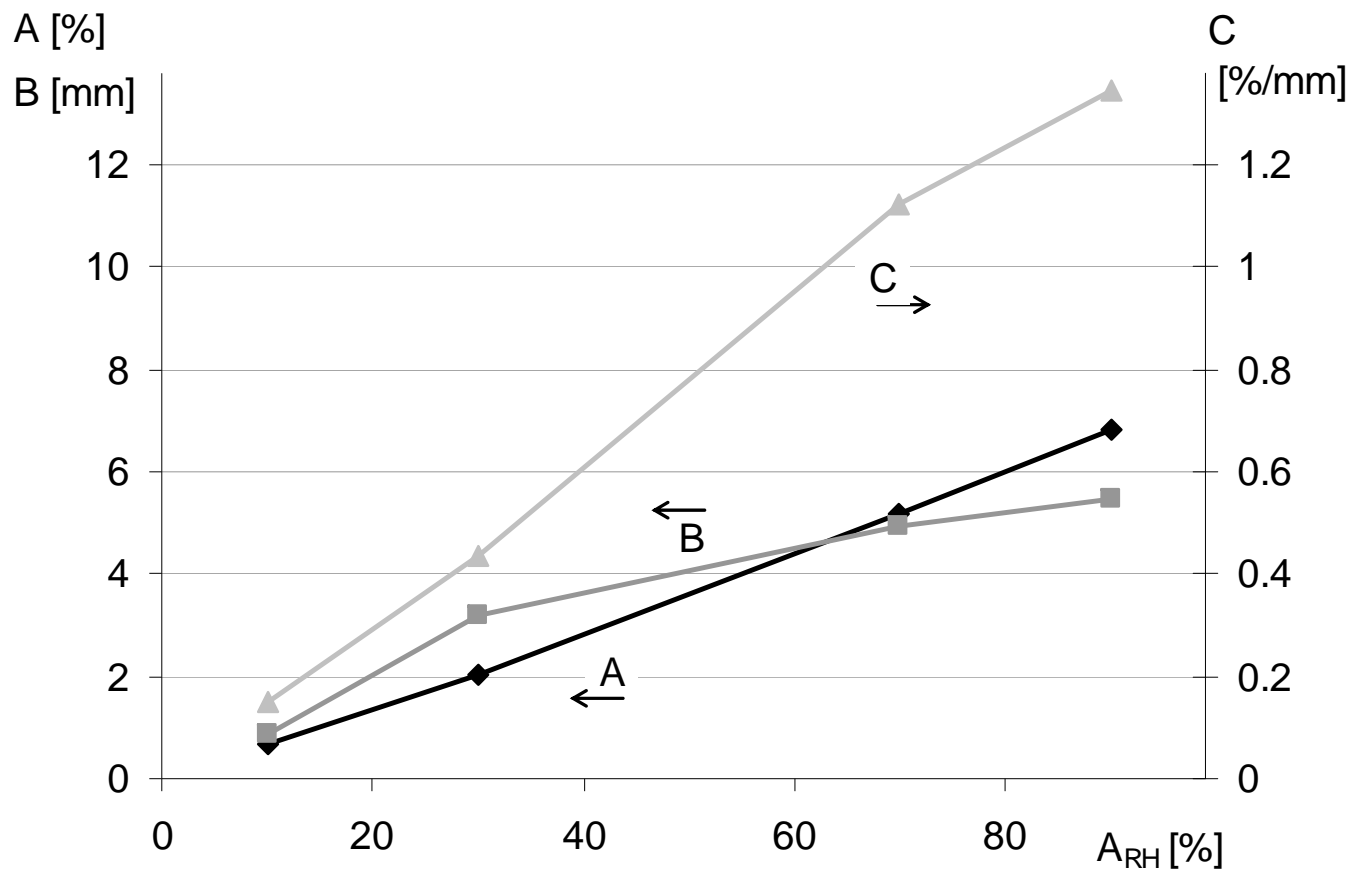
Pure harmonic action and response



Numerical calculations

Pure harmonic action and response

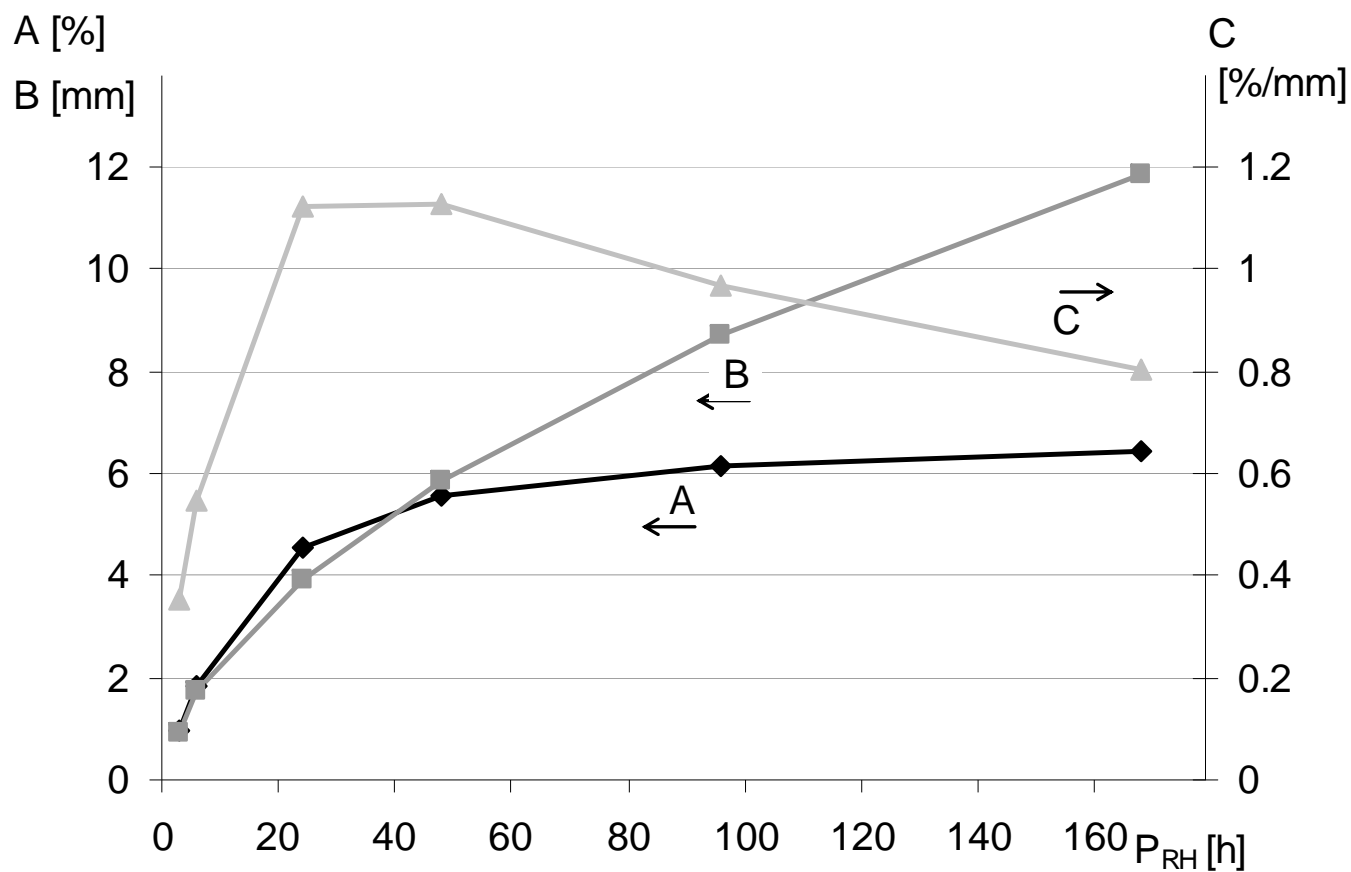
Varying amplitude, constant daily period and mean value



Numerical calculations

Pure harmonic action and response

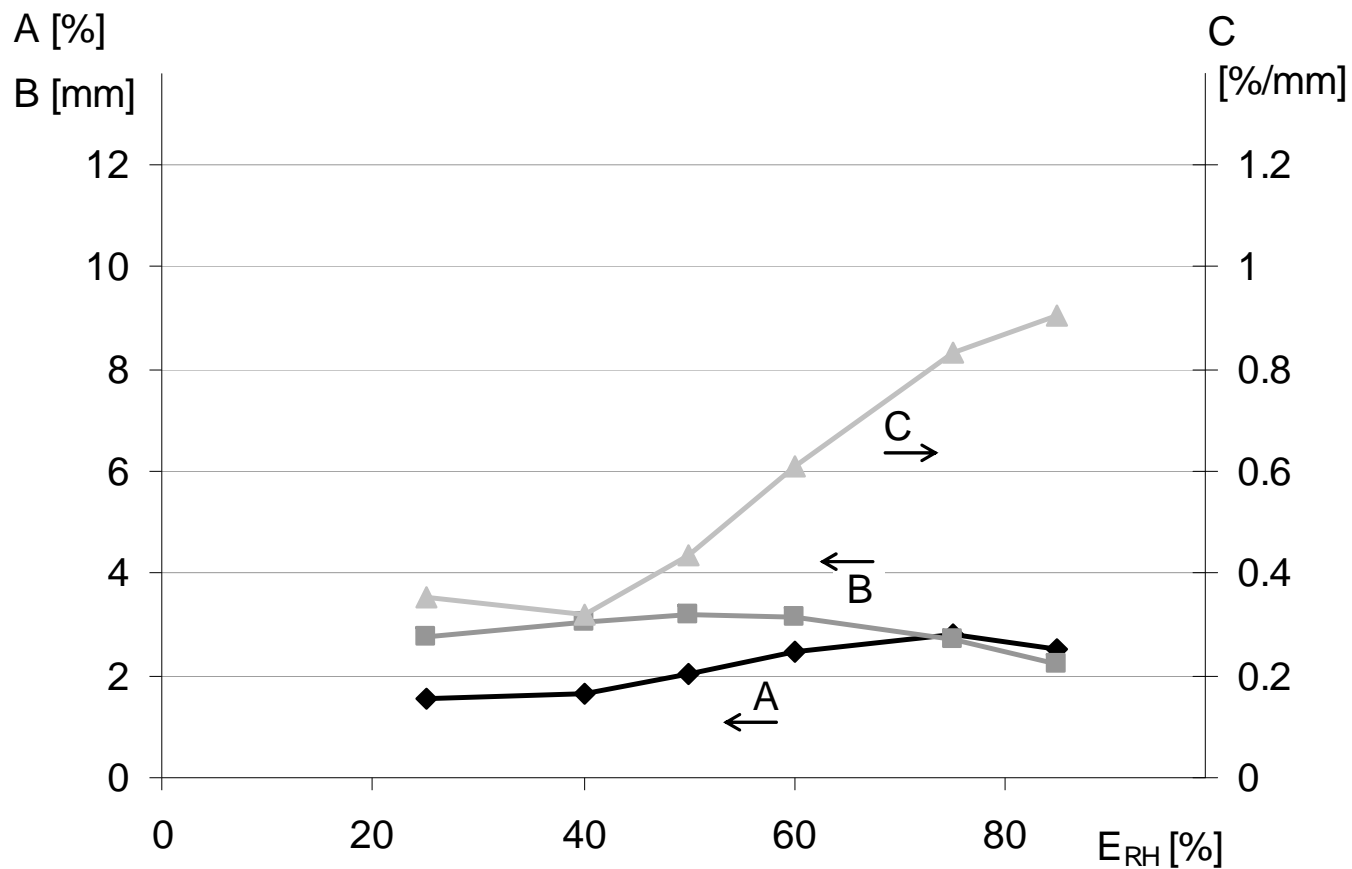
Varying period, constant amplitude and mean value



Numerical calculations

Pure harmonic action and response

Varying period, constant amplitude and mean value



Remarks and conclusions

- Wood moisture – Air humidity hysteresis is significant for moisture state
- Wood moisture state is the (weak boundary) condition for moisture induced stress calculation.
- The moisture state response to a the combination of step change and sinusoid variation of humidity is a superposition of the responses of the individual humidity excitation.