Moisture transport in seasoned wood

Coupled diffusion model and model sensitivity

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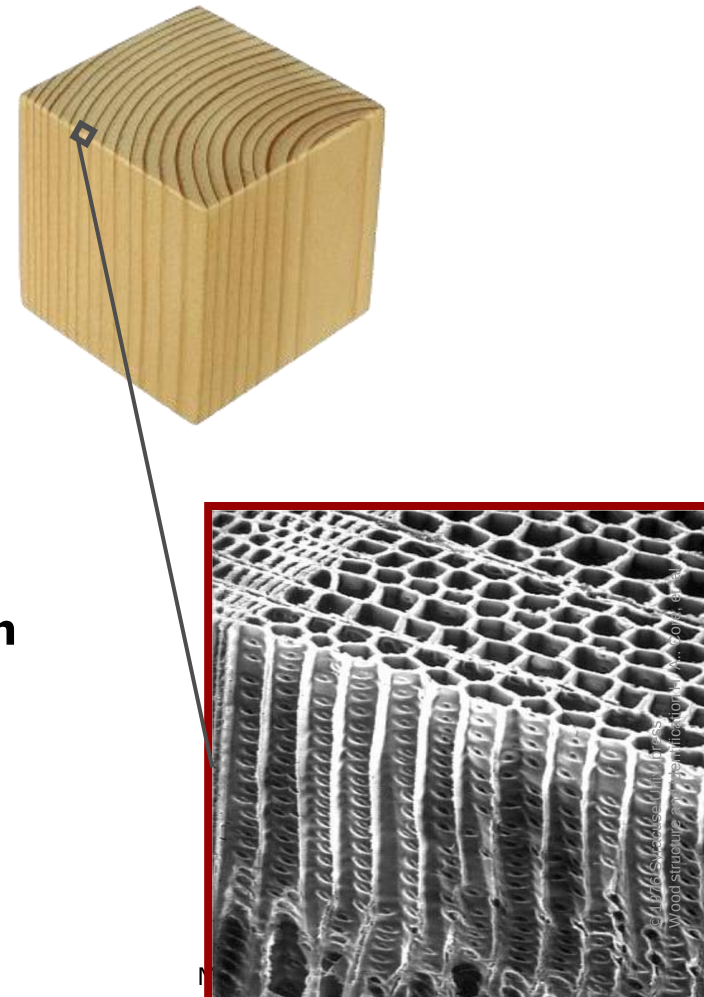
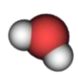
Wood, a open porous material

Softwood has a porosity of 60 – 70 % and an open accessible pore system



Type	**size [μm]**
Pits	**5 – 20**
Lumen	**10 – 40**
Rays	**20 – 100**
Resin canal	**30 – 100**

The water molecule is <u>0.3 nm</u> or 0.0003 μm



Vapor diffusion in woods pore-system

- Water vapor traverses in the lumens and other open pores of wood.
- Diffusion moves vapor[#].
- The flow, q_v, of vapor; also in the porous system of wood; is described by Fick's law of diffusion.

$$q_v = -D_v \frac{\partial \mu}{\partial x}$$

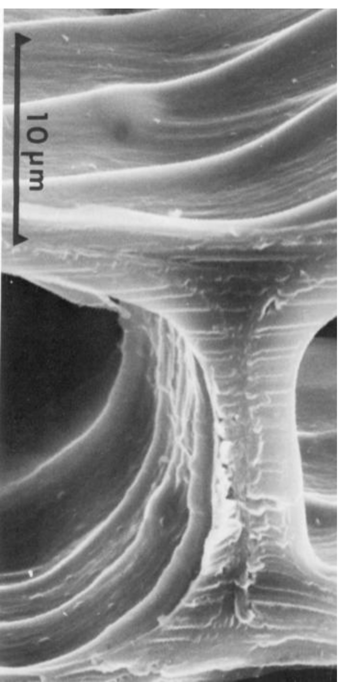
where D_v is the diffusivity of water vapor in air, μ the driving potential and x the spatial coordinate.

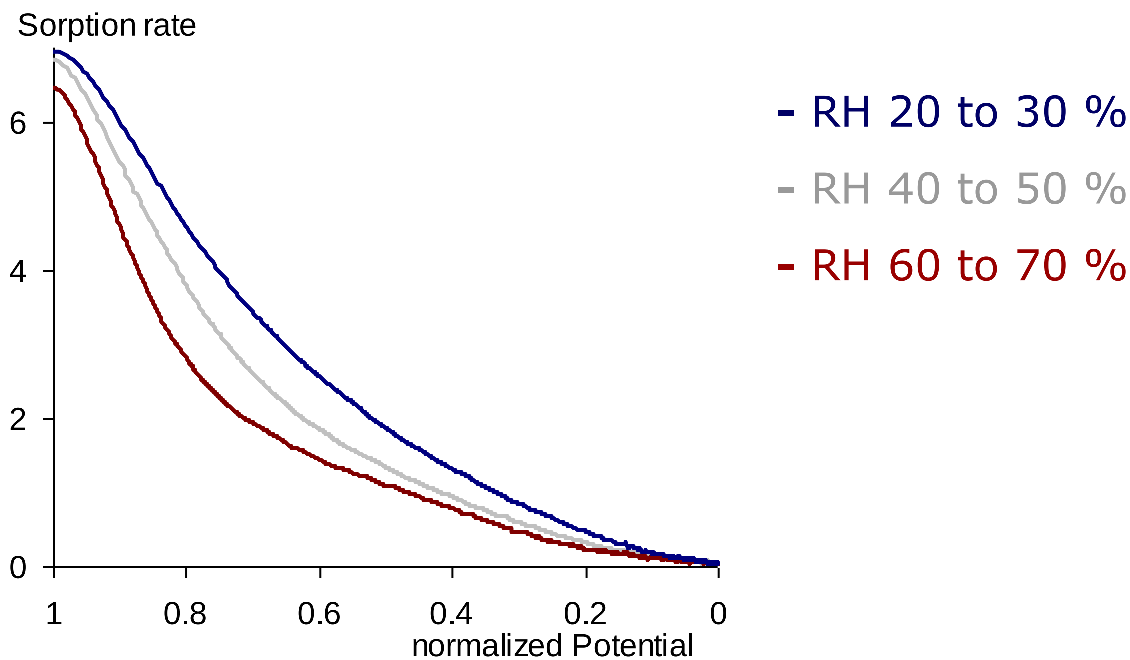
convection in the porous system is considered non-significant

Hygroscopic behavior of wood cell wall

- Every cell wall layer adjacent to lumen, rays, etc is the dividing entity (surface) between the solid wood material and vapor phase.

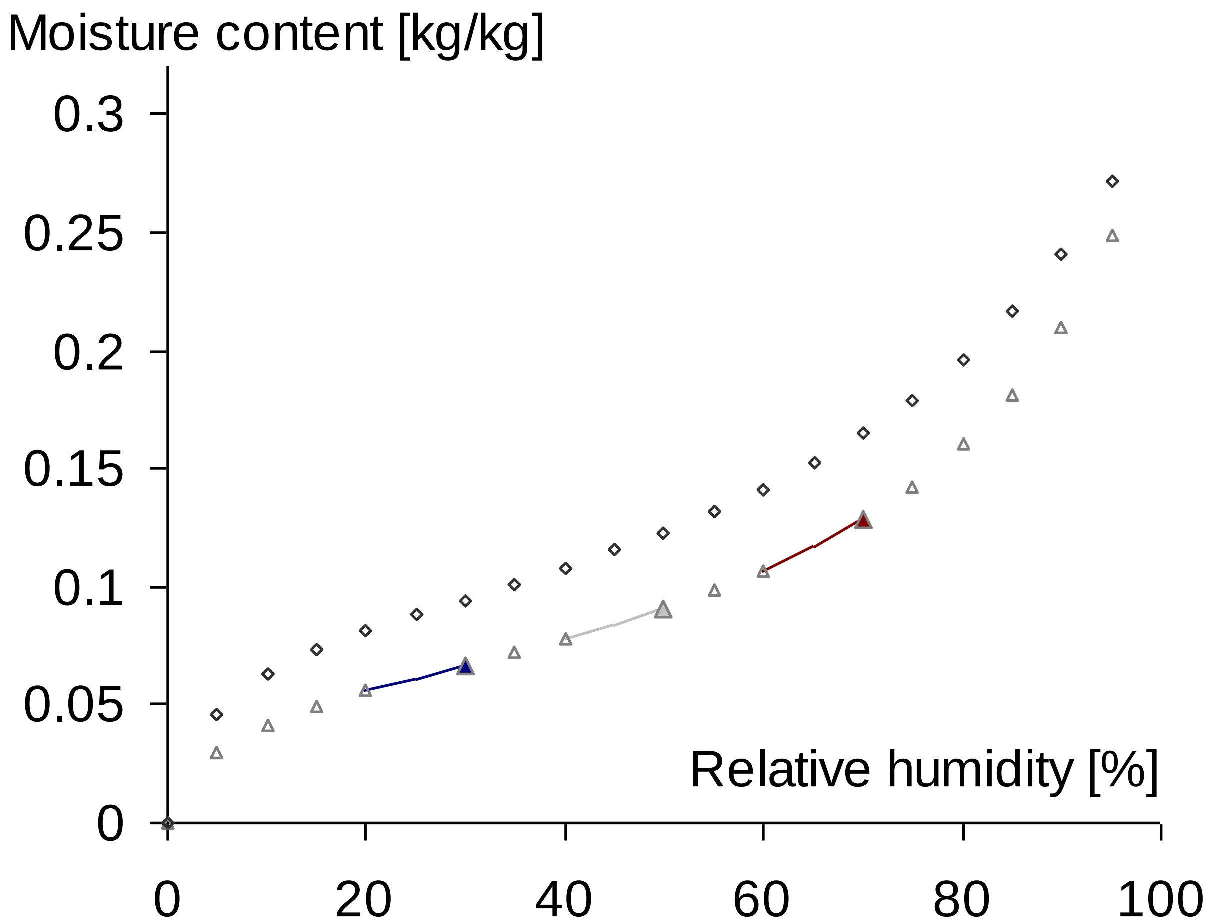
- Water and cell wall material interacting, with hydrogen bonds.
- Water sorption is a phase change involving both heat and mass transfer.
- Sorption is state dependent

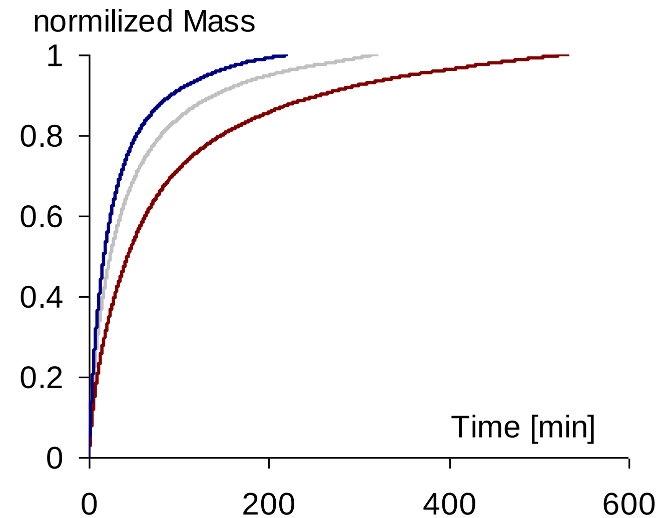




Sorption Isotherm
Equilibrium moisture states

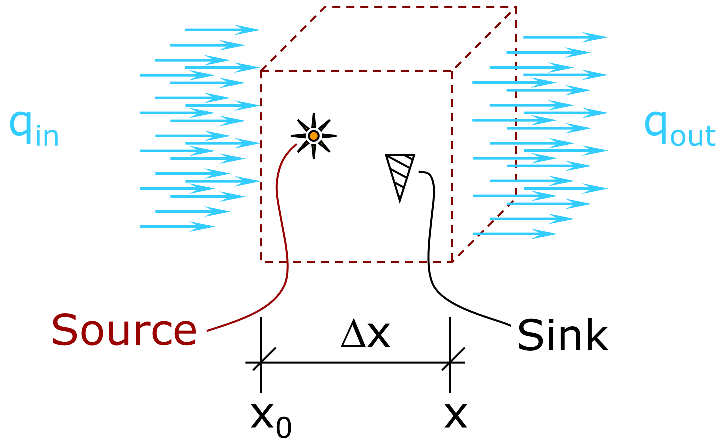
- The transient process is only isotherm at equilibrium states.





Mass balance of moisture transport in wood

$$\frac{\partial m}{\partial t} = \frac{\partial q_m}{\partial x} + \frac{\partial \hat{m}}{\partial t}$$



When normalized with the volume:

$$\frac{\partial c}{\partial t} = \frac{\partial q_c}{\partial x} + \frac{\partial \hat{c}}{\partial t}$$

where concentration, c = m/V

The source and the sink are together the mathematical representation of sorption

Vapor transport in wood

Is mathematically derived by combining mass balance with Fick's law:

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(D_v \frac{\partial c}{\partial x}\right) + \frac{\partial \hat{c}}{\partial t}$$

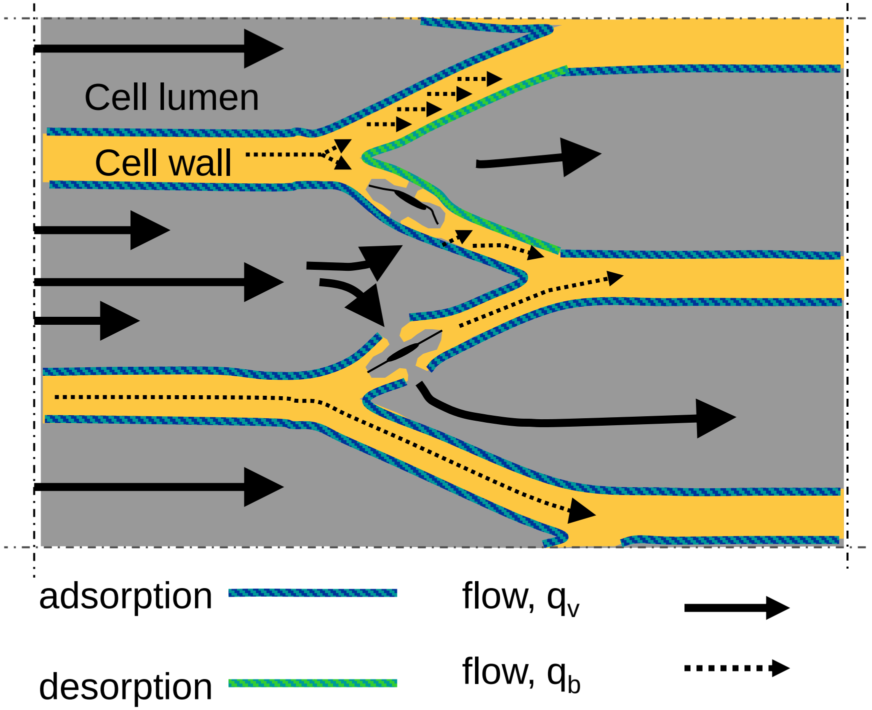
To account for the transport in the cell wall, the same reasoning holds. One have to remember, however, that when mass appears in a cell wall it disappears as vapor in a pore.

Moisture transport in wood

Is mathematically derived by combining mass balance with Fick’s law twice:

$$\frac{\partial c_v}{\partial t} = \frac{\partial}{\partial x}\left(D_v \frac{\partial c_v}{\partial x}\right) + \frac{\partial \hat{c}}{\partial t}$$

$$\frac{\partial c_b}{\partial t} = \frac{\partial}{\partial x}\left(D_b \frac{\partial c_b}{\partial x}\right) - \frac{\partial \hat{c}}{\partial t}$$



Coupled models

- Coupled processes causes experimental difficulties when determining constitutive relations.

  Material parameters are state dependent
  The state is defined by the processes

- Stationary, transient and cyclic excitation provoke difference in response.

- Sensitivity analysis of the model is a method that can be used for designing useful experimental research.

Sensitivity index and studied outcome

$$SI_{f_i} = \frac{COV(f_i(X))}{COV(X_i)}$$

The Sensitivity influence shows the influence of an input parameter on the model outcome.

X represents the material parameters; vapor diffusivity, bound water diffusivity and sorption rate function. X_i is variations of one material parameter

Three model outcomes:

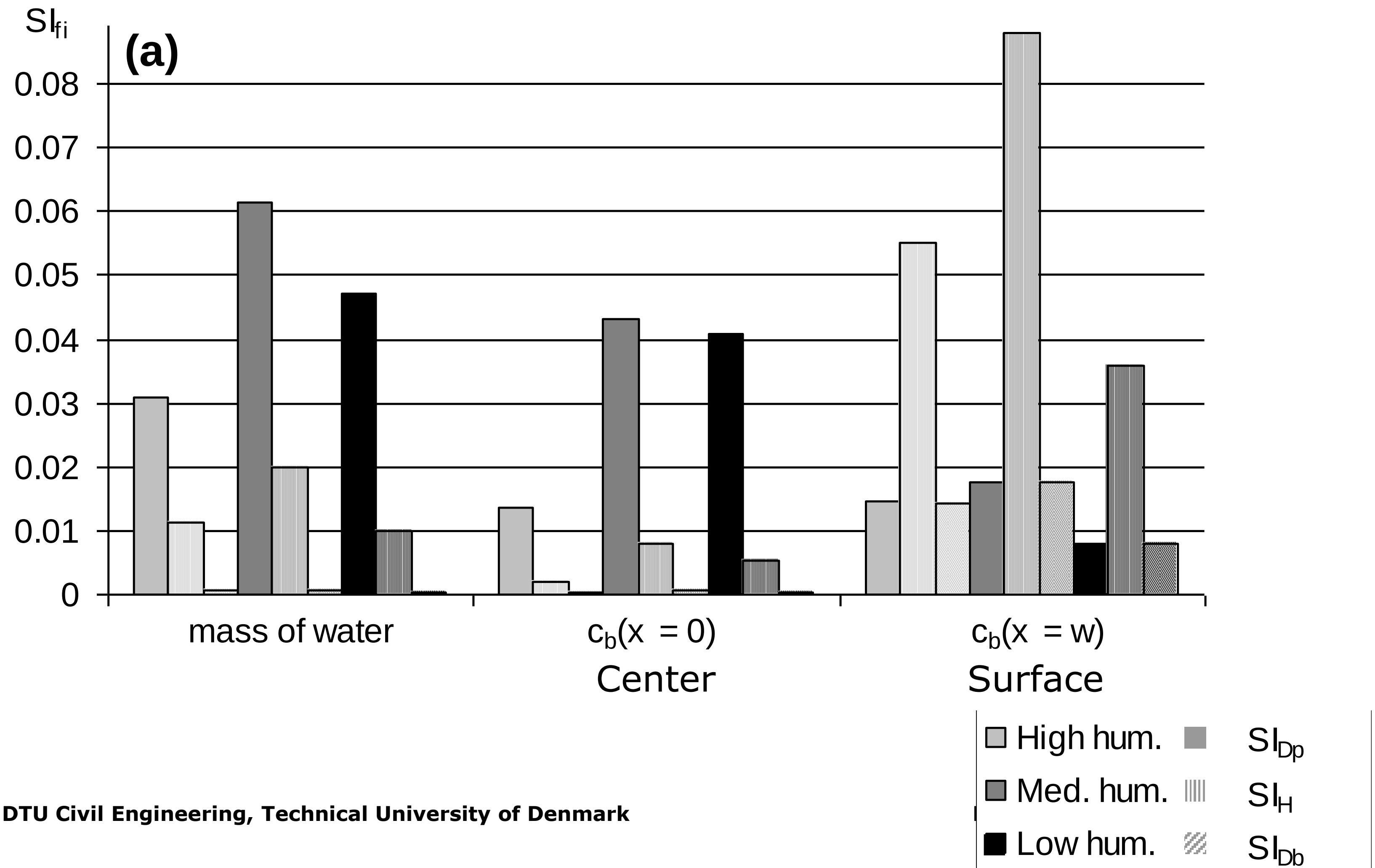
Total mass change

Concentration of bound water at closed boundary

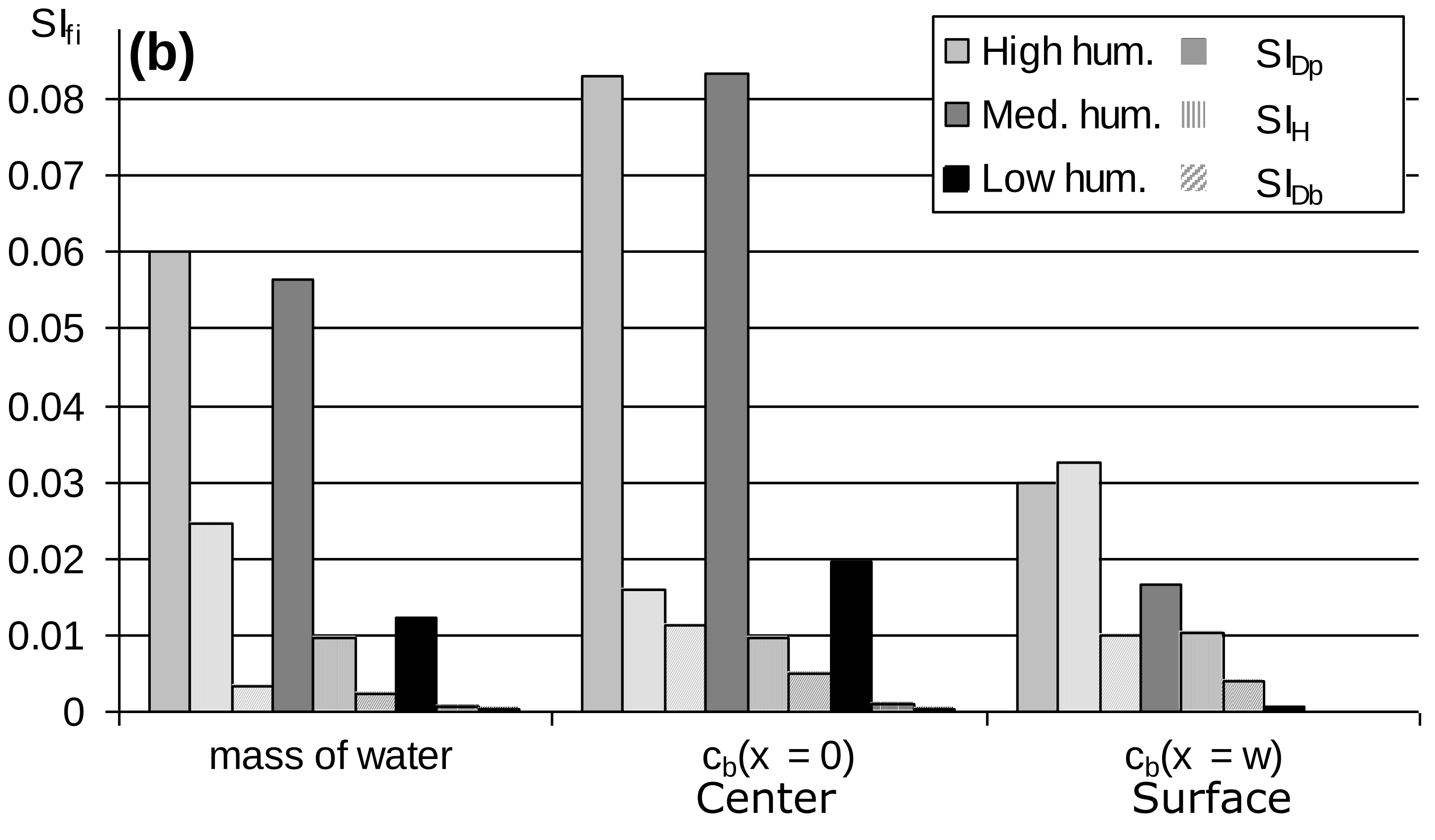
Concentration of bound water at open boundary

at two times in the process have been studied as a result of a uniform step change of boundary condition for three different states.

Model sensitivity early in process



Model sensitivity late in process



Conclusions

The simplest model for predicting moisture transport in the open porous material (wood) is a coupled model.

In the hygroscopic range three process; diffusion of vapor in pore system, sorption and diffusion of bound water; constitute the moisture transport of wood.

Model sensitivity may be used to identify what process and material parameter that have influence on measurements in a test.