

# Moisture Induced Stresses

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# M.I.S.

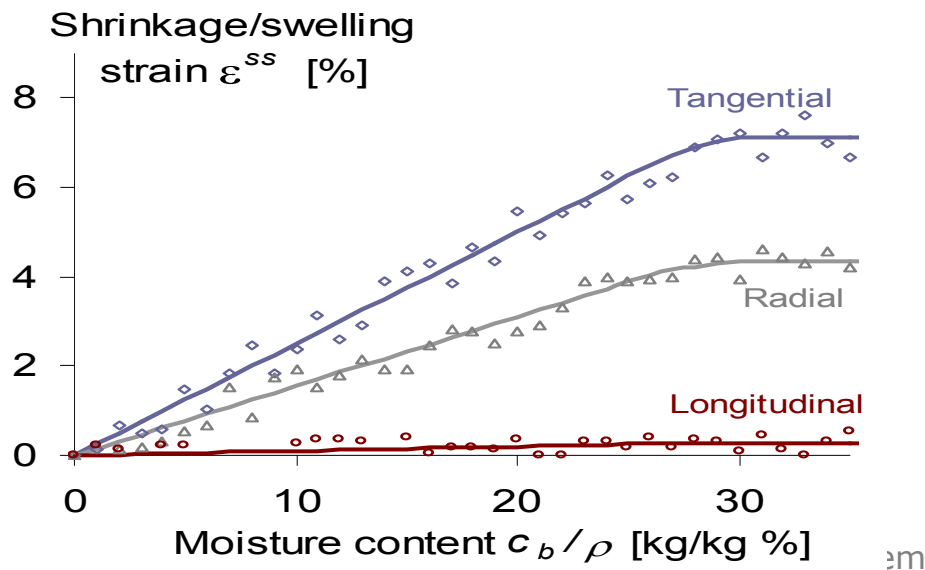
- **Eigenstresses independent of external mechanical load**
- **Stress states altered by moisture sorption**
- **Accelerated aging (DOL) as a result of moisture state and history**

# Fundamental mechanics

- **Mechano-sorptive strain**
- **Time delayed strain (visco-elastic and viscous)**
- **Elastic strain**
- **Shrinkage and swelling**
  - Direction dependent material *(anisotropic & porous)*
  - Natural variation on all levels *(heterogeneous & stochastic)*
  - In constant H<sub>2</sub>O interaction *(hygroscopic)*

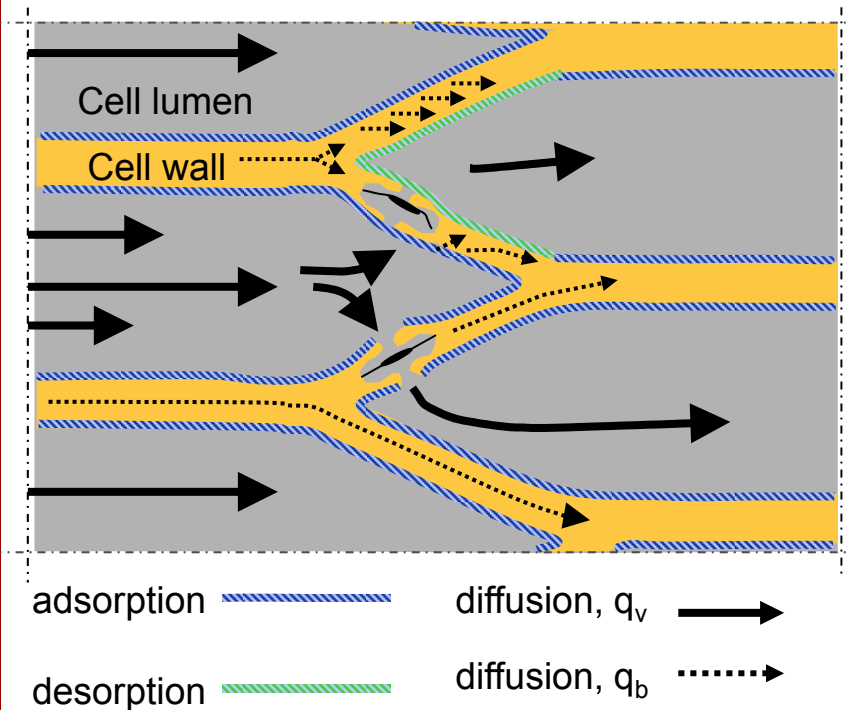
# The hygro in hygro-mechanics

- $\dot{\varepsilon}_{ms} = f(\sigma, \varepsilon_{ms}, \dot{u}, T, \dots)$
- $\dot{\varepsilon}_v = f(\sigma, \varepsilon_v, u, T, t, \dots)$
- $E_{ijkl} = E_{ijkl}(u, T)$



# Moisture transport in wood

The three constitutive equations and the condition of mass conservation gives the two coupled transport equations:



## Governing equations

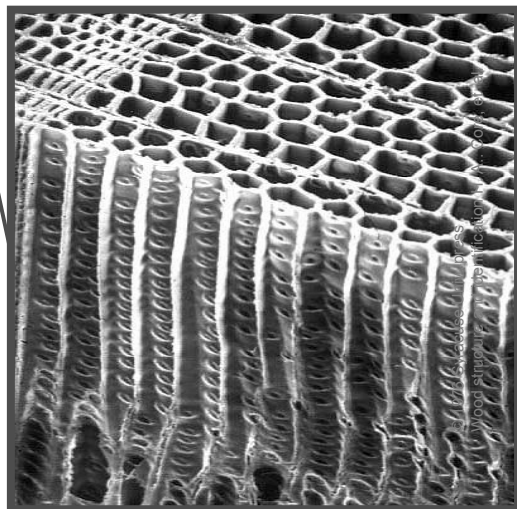
$$\frac{\partial c_v}{\partial t} = \nabla \cdot (\mathcal{D}_v \nabla c_v) + \dot{s}$$

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

## with boundary conditions

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

# Influence of material structure-anatomy



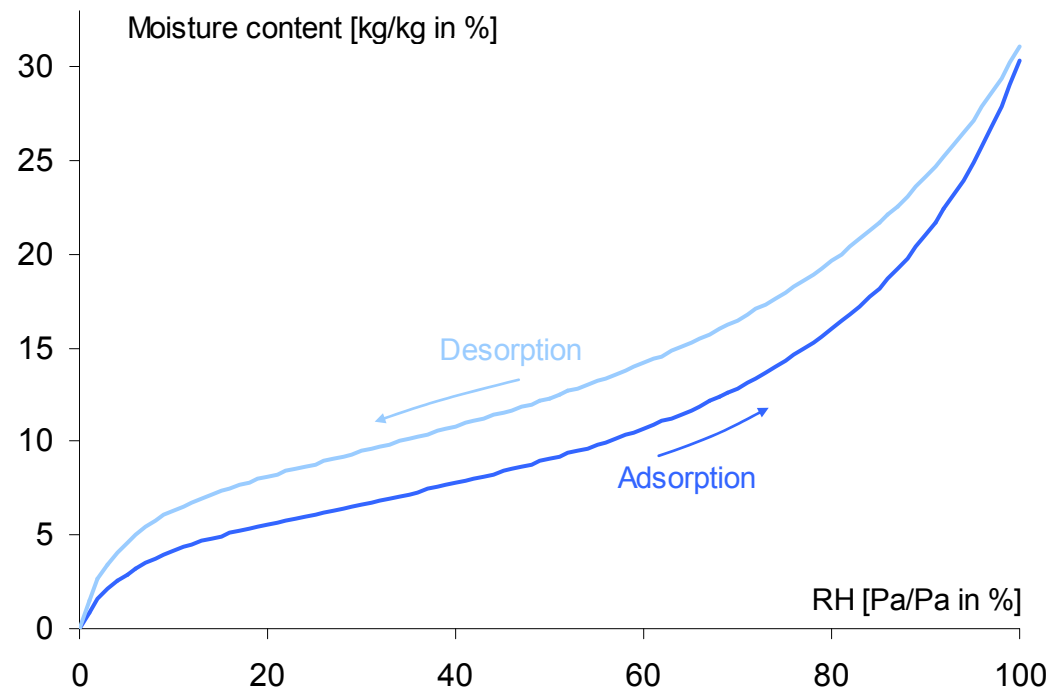
Softwood has a porosity of c.a. 0.6 and an open accessible pore system

<u>Type</u>	<u>size (cross-sect.)</u>
Pits	5 – 20 $\mu\text{m}$
Lumen	10 – 40 $\mu\text{m}$
Rays	20 – 100 $\mu\text{m}$
Resin canal	30 – 100 $\mu\text{m}$

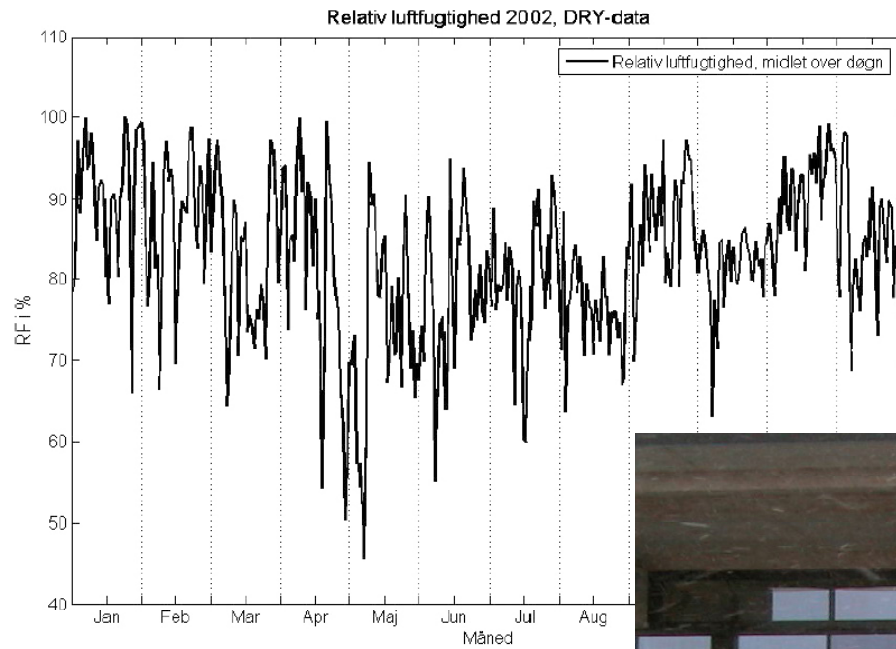
The water molecule is c.a. 0.3 nm in diameter and the average distance of two water-vapor molecules at 20° C and saturated is c.a. 12 nm

# Moisture uptake or Sorption

Sorption takes place in the whole domain,  $\Omega$ , not only on the macroscopic boundary



# Natural varying climate



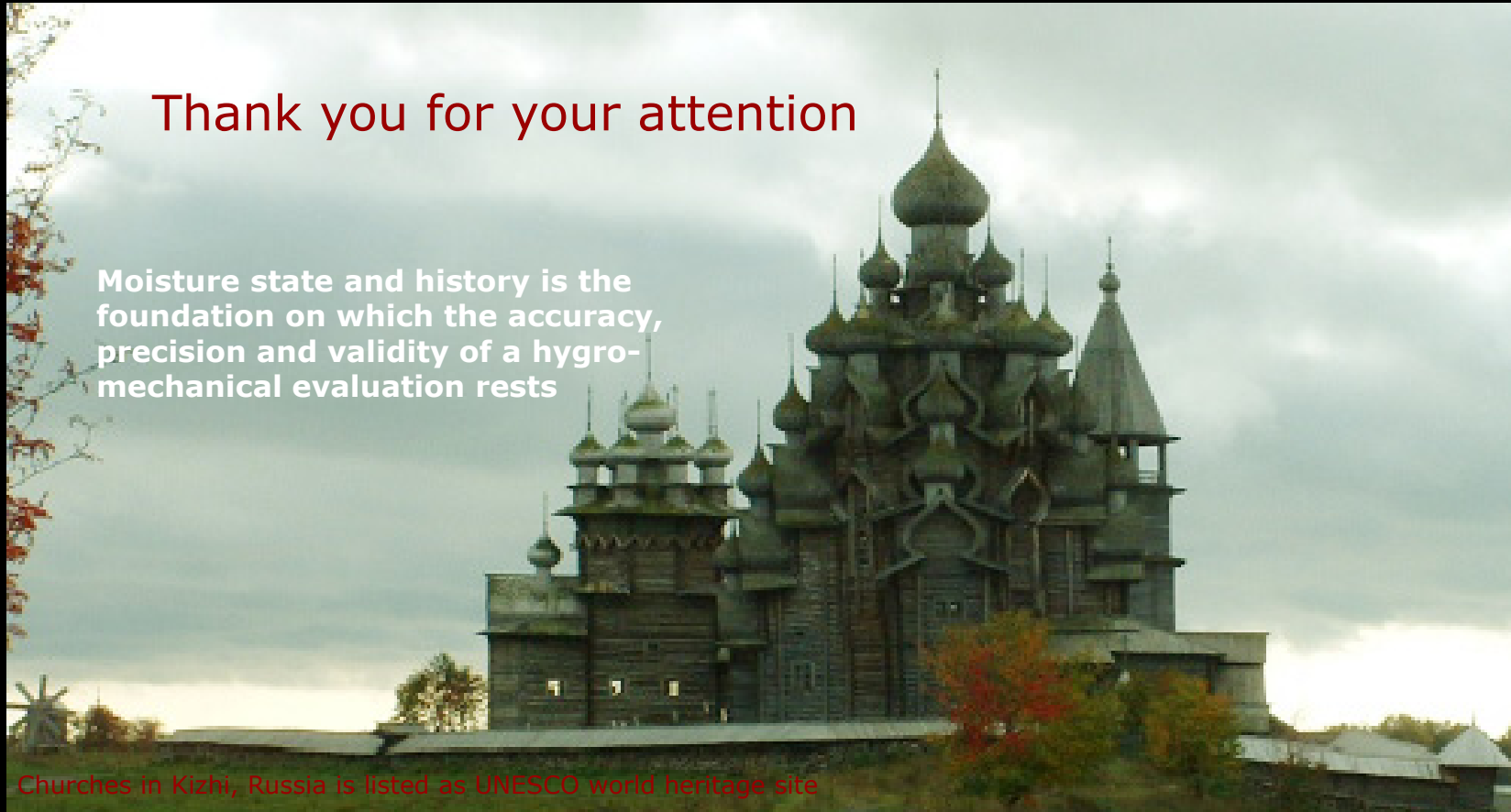
CostE55, Trondhjem



Thank you for your attention

Moisture state and history is the foundation on which the accuracy, precision and validity of a hygro-mechanical evaluation rests

Churches in Kizhi, Russia is listed as UNESCO world heritage site



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