Models for moisture transport and material response to duration of excitation in combination with varying moisture state.

Staffan Svensson

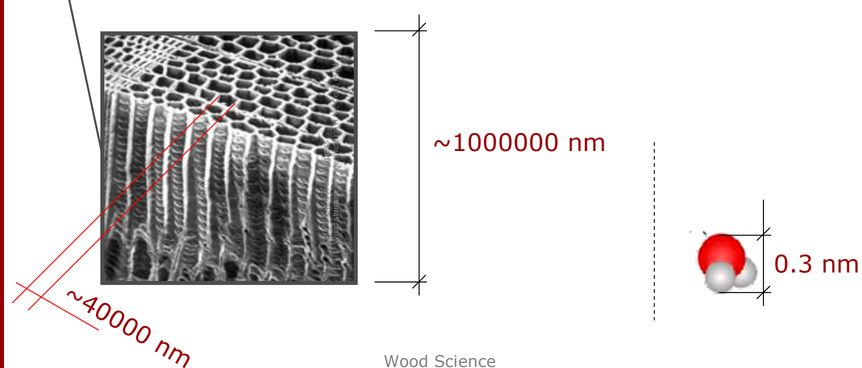
Technical University of Denmark
Department of Civil Engineering (DTU•BYG)

Conclusion

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

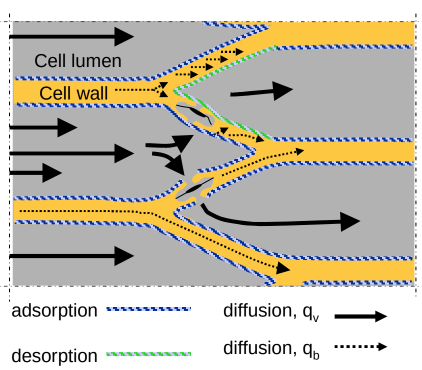
Moisture transport in seasoned wood with no direct contact with liquid water

Stamm (1959, 1960) Moisture transport in wood is a coupled diffusion phenomenon: diffusion of vapor in the open porous system, sorption on all surfaces (internal) and diffusion of bound water.



Moisture transport in wood

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



Governing equations

$$\frac{\partial c_v}{\partial t} = \nabla (D_v \nabla c_v) - \dot{s}$$

$$\frac{\partial c_b}{\partial t} = \nabla (D_b \nabla c_b) + \dot{s}$$

with boundary conditions

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

$$\hat{n}_\Gamma q_b = 0$$

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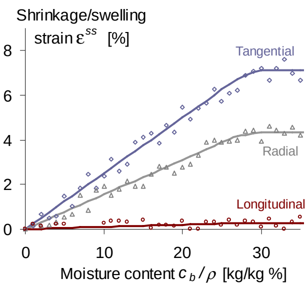
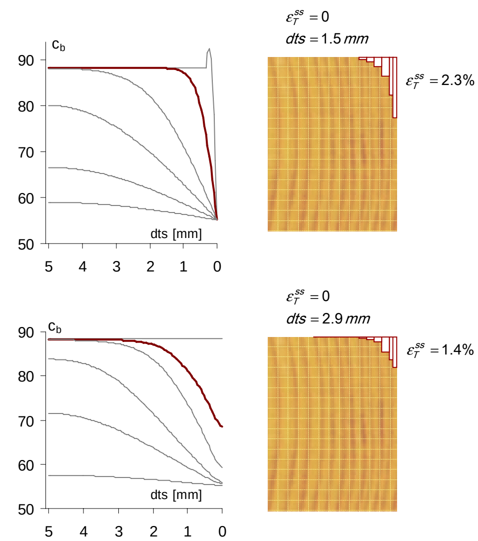
Moisture profiles and constrained shrinkage





$$\varepsilon^{ss} \propto \frac{c_b}{\rho} \qquad \frac{c_b}{\rho} < u_{FSP}$$

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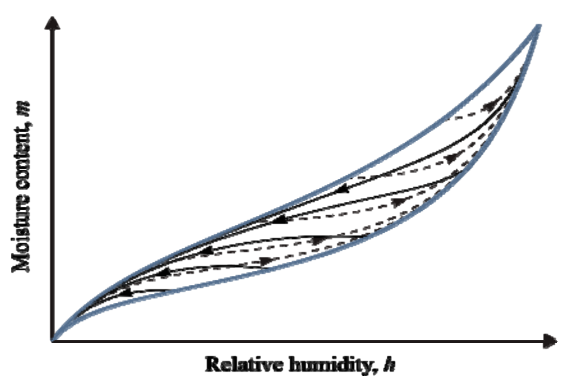
Hysteresis



1) No unique relation between moisture state in wood and ambient humidity.
2) The response to a change in ambient humidity is history dependent.

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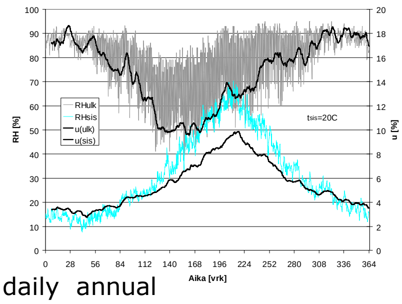
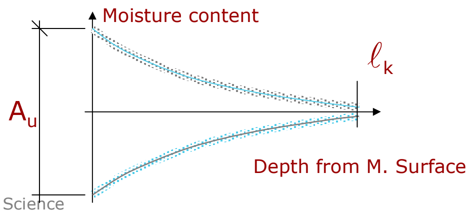
From model to code

A reliable code must be founded on accurate and precise models for moisture transport, sorption and shrinkage

Ever varying climate



Depth and amplitude, daily annual variations



$A_u = \overline{}\ A_{RH}, f_{RH}, T)$

$\ell_k = \mathcal{F}(\overline{RH}, A_{RH}, f_{RH}, T)$

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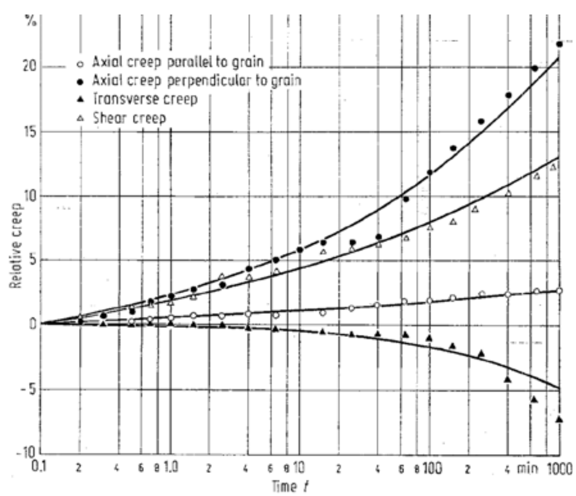
Creep (and relaxation) is not 1D



Visco-elastic, Viscous or Mechano-sorption properties can not be "up-scaled" from 1 D to higher dimensions in proportion to elastic properties!

Schniewind and Barrett 1972

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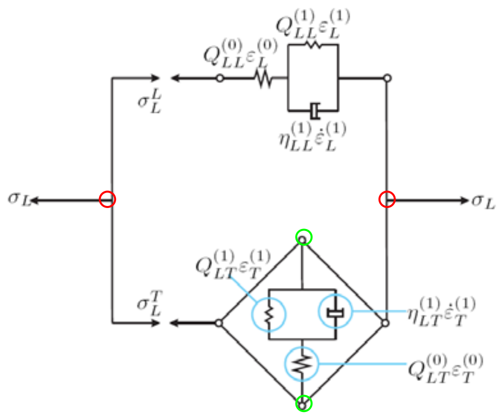
Creep in two dimensions



$$\begin{bmatrix}\sigma_L\\ \sigma_T\\ \tau_{LT}\end{bmatrix}=\begin{bmatrix}Q^{(0)}_{LL} & Q^{(0)}_{LT} & 0\\ Q^{(0)}_{TL} & Q^{(0)}_{TT} & 0\\ 0 & 0 & G^{(0)}_{LT}\end{bmatrix}\begin{bmatrix}\varepsilon^{(0)}_L\\ \varepsilon^{(0)}_T\\ \gamma^{(0)}_{LT}\end{bmatrix}$$

$$\begin{bmatrix}\sigma_L\\ \sigma_T\\ \tau_{LT}\end{bmatrix}=\begin{bmatrix}Q^{(1)}_{LL} & Q^{(1)}_{LT} & 0\\ Q^{(1)}_{TL} & Q^{(1)}_{TT} & 0\\ 0 & 0 & G^{(1)}_{LT}\end{bmatrix}\begin{bmatrix}\varepsilon^{(1)}_L\\ \varepsilon^{(1)}_T\\ \gamma^{(1)}_{LT}\end{bmatrix}+\begin{bmatrix}\eta^{(1)}_{LL} & \eta^{(1)}_{LT} & 0\\ \eta^{(1)}_{TL} & \eta^{(1)}_{TT} & 0\\ 0 & 0 & \eta^{(1)}_{LTS}\end{bmatrix}\begin{bmatrix}\dot{\varepsilon}^{(1)}_L\\ \dot{\varepsilon}^{(1)}_T\\ \dot{\gamma}^{(1)}_{LT}\end{bmatrix}$$

$$\varepsilon=\sum_{n=0}^{N}\varepsilon^{(n)}$$

○ Deformation, strain in load direction
○ Deformation, strain in transverse direction

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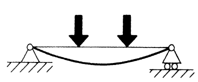
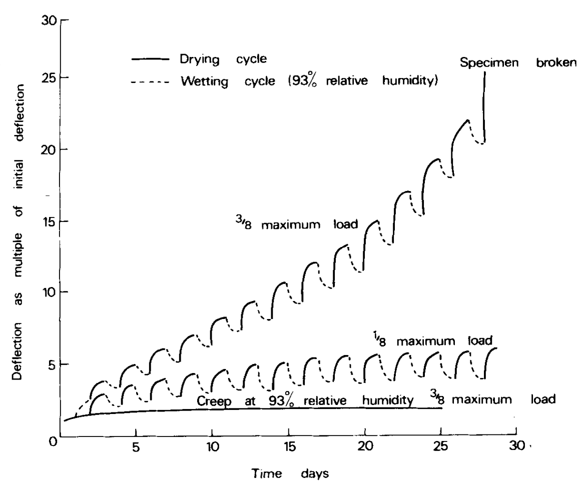
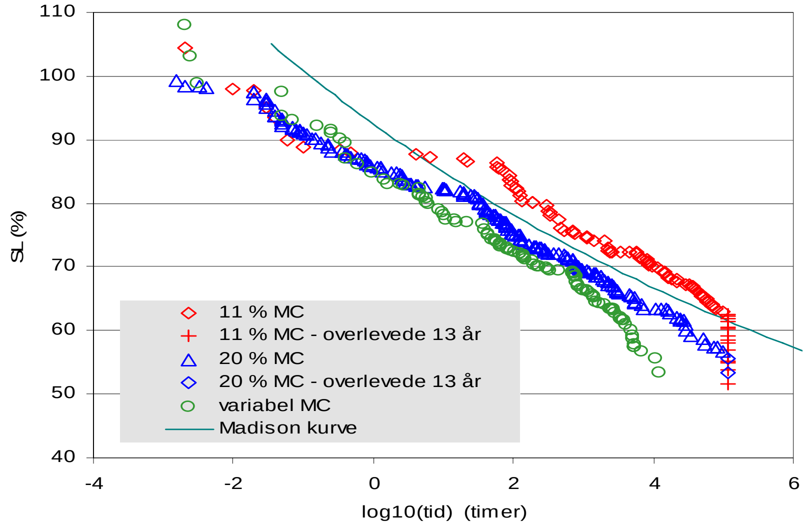
Duration of load accelerated by moisture



Famous test on mechano-sorption by Armstrong & Kingston 1960



One result (Hoffmeyer)



Challenges

More experimental work on moisture transport and sorption.

More experimental work on moisture hysteresis

More experimental work on creep 2D and 3D

DOL must be tested with new reliable and less time consuming method

Unified theory for creep and effect of load duration