Effect of moisture to the strength and deformations of timber structures

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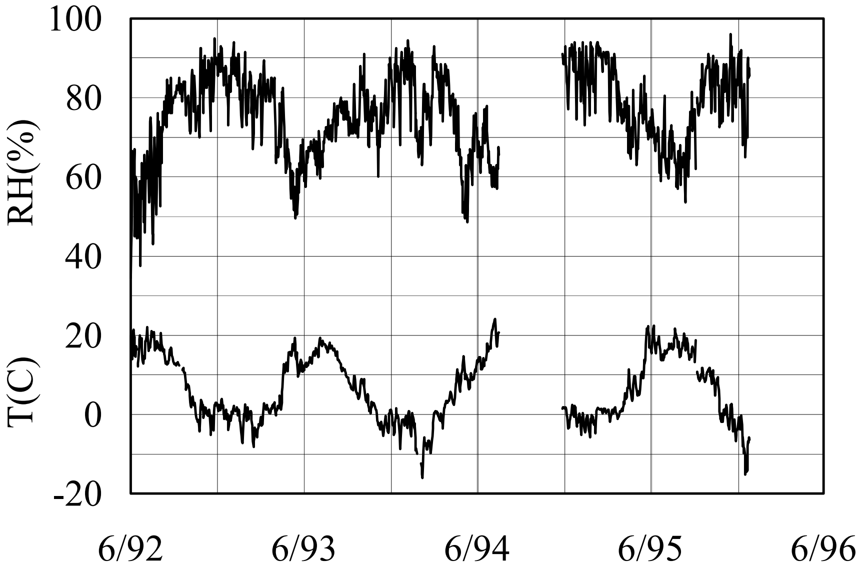
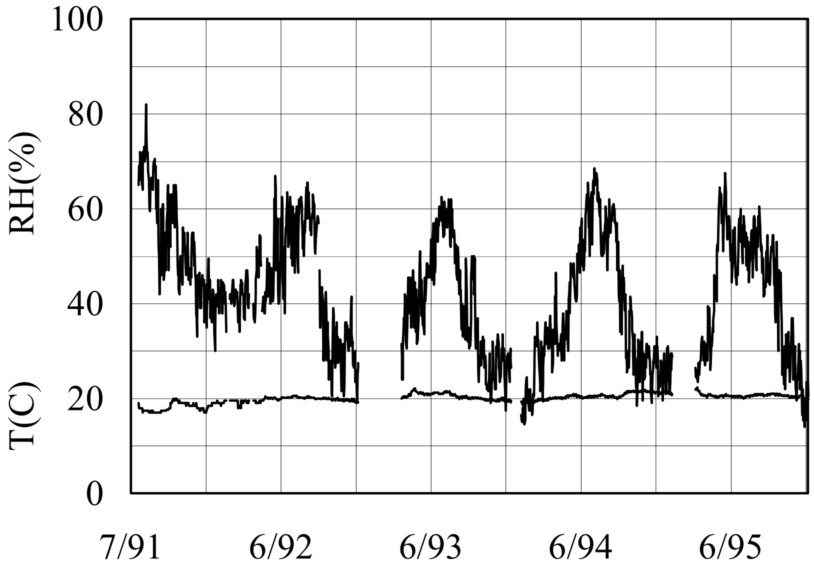
- **Moisture content in wood**
- **Strength at different moisture contents**
- **Creep and moisture variation**
- **Strength reduction due to moisture gradients**

Relative humidity in Finland

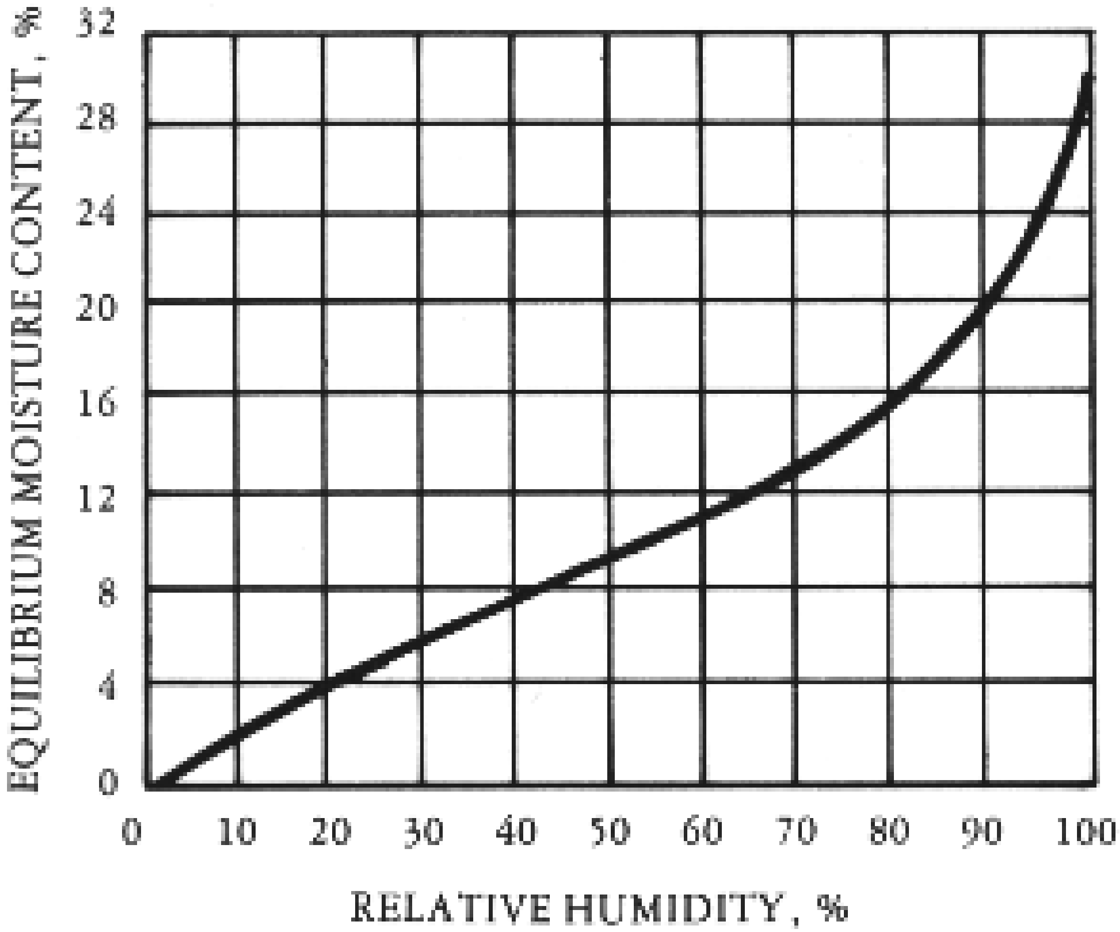
outdoors



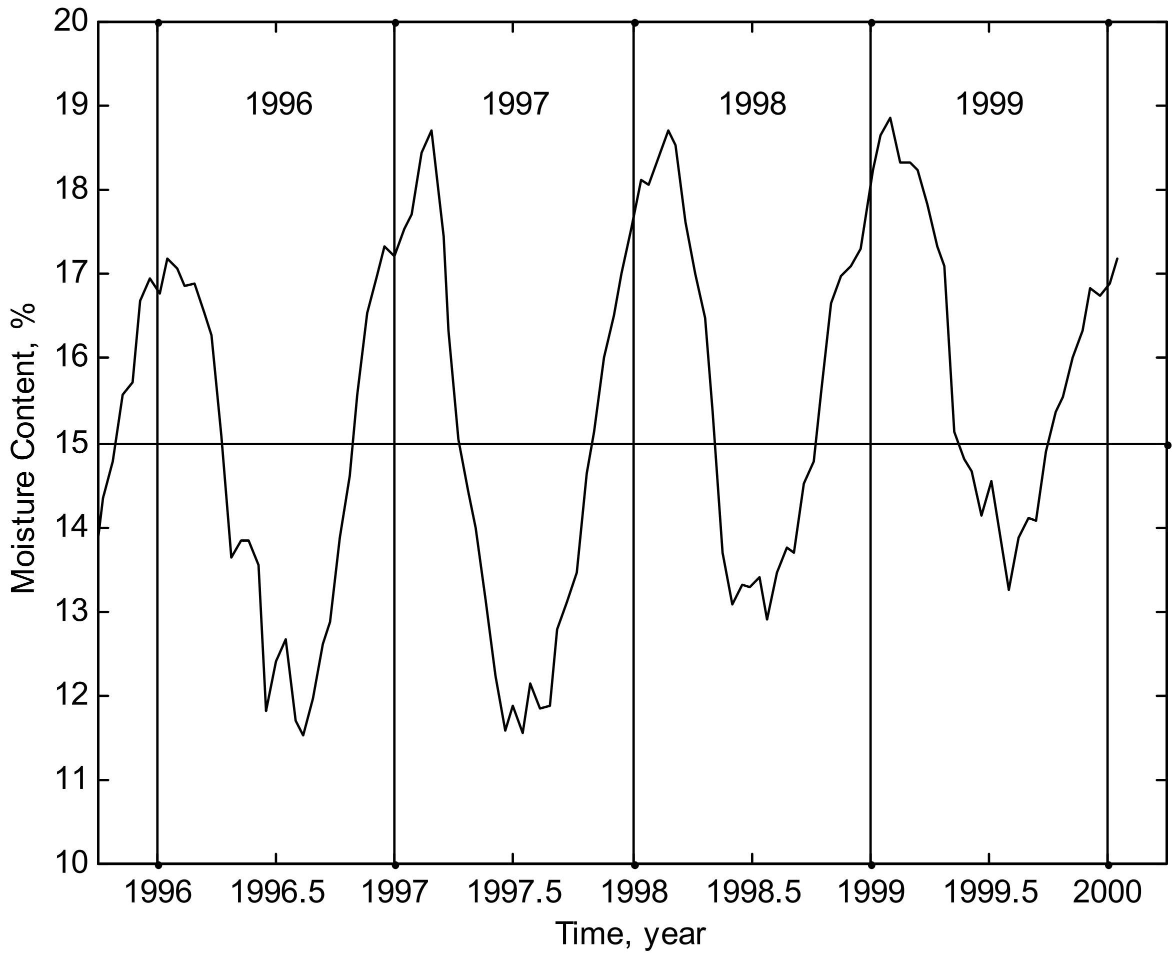
indoors



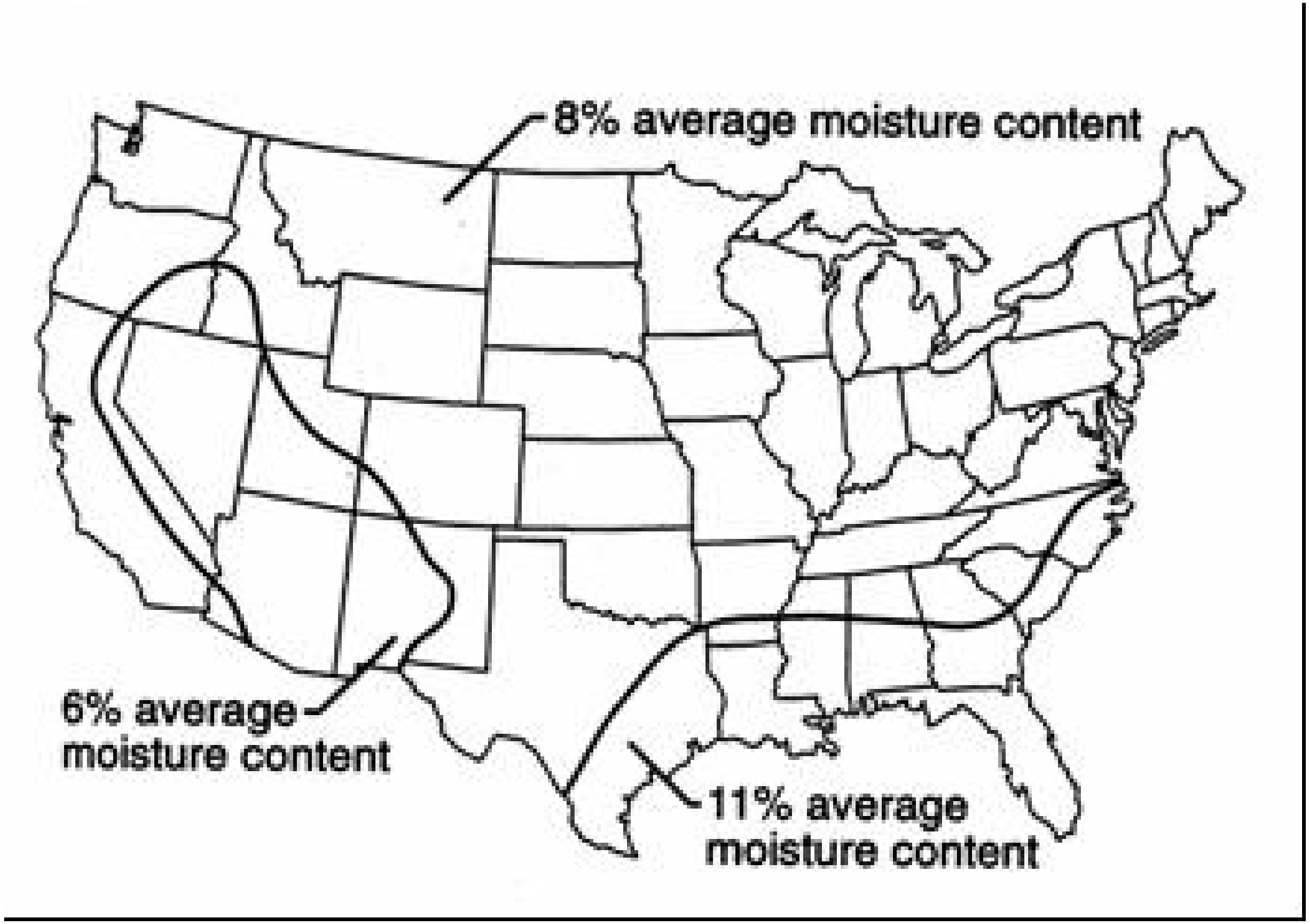
Equilibrium moisture content of wood



Moisture content variation in southern Sweden



Recommended MC of wood for interior use

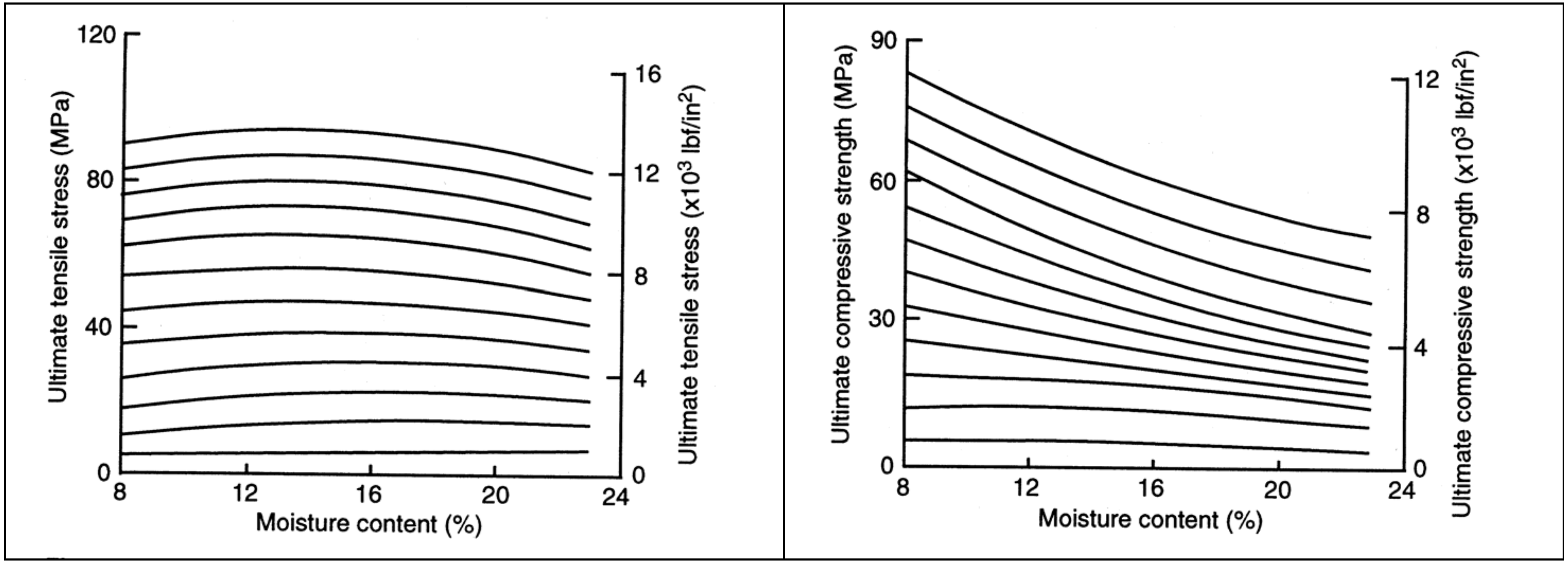


Effect of moisture content change to mechanical properties of softwoods (%/%) between 8 and 20% MC.

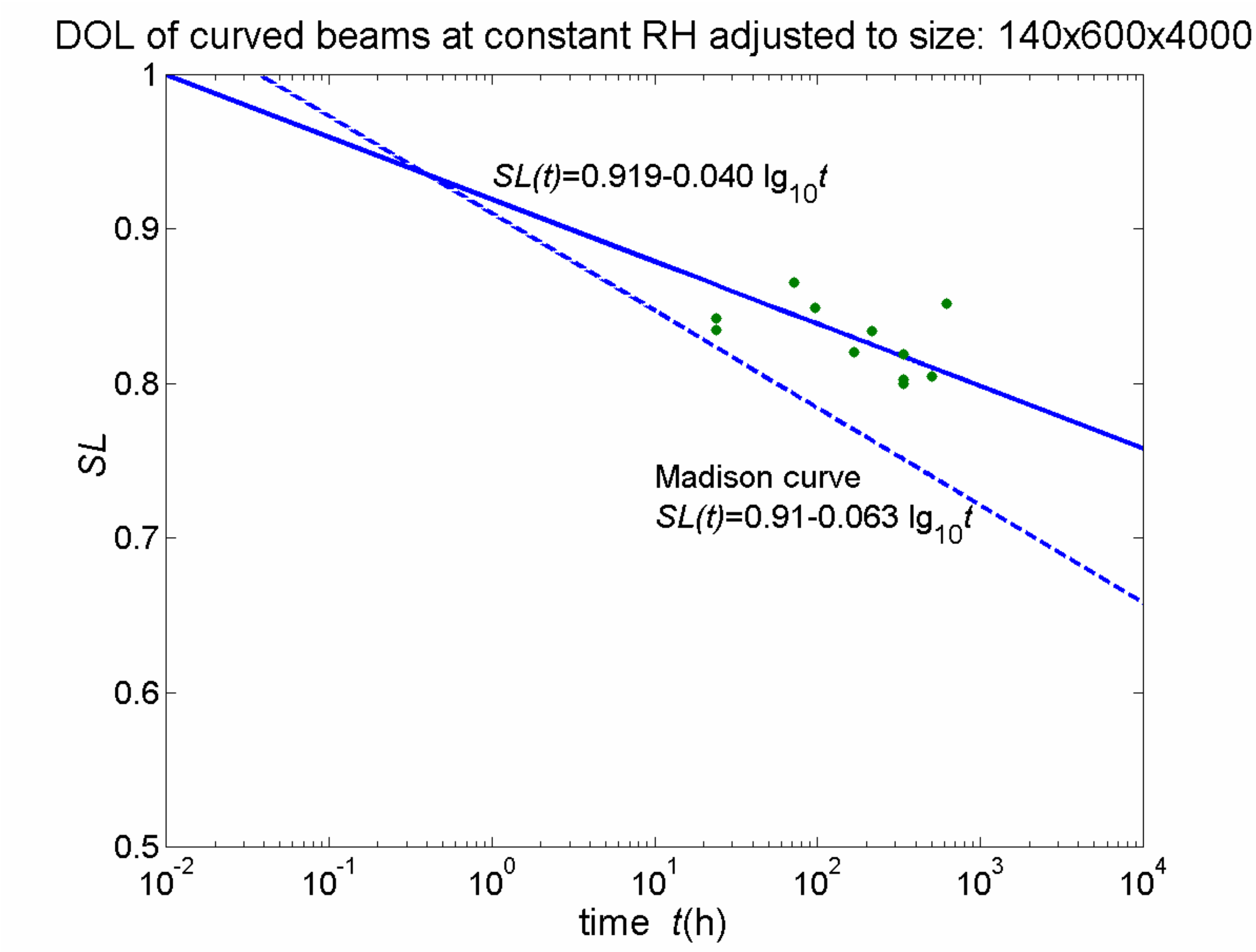
Values of clear wood and round timber are average effects, values of sawn timber are for characteristic values

Property	Clear wood	Round timber	Sawn timber (EN 384)
Compression strength	5	5	3
Bending strength	4	1	0
Tension strength (//)	2,5		0
Tension strength (⊥)	2		
Shear strength	3		
Impact bending strength (//)	0,5		
Modulus of elasticity (//)	1,5		2

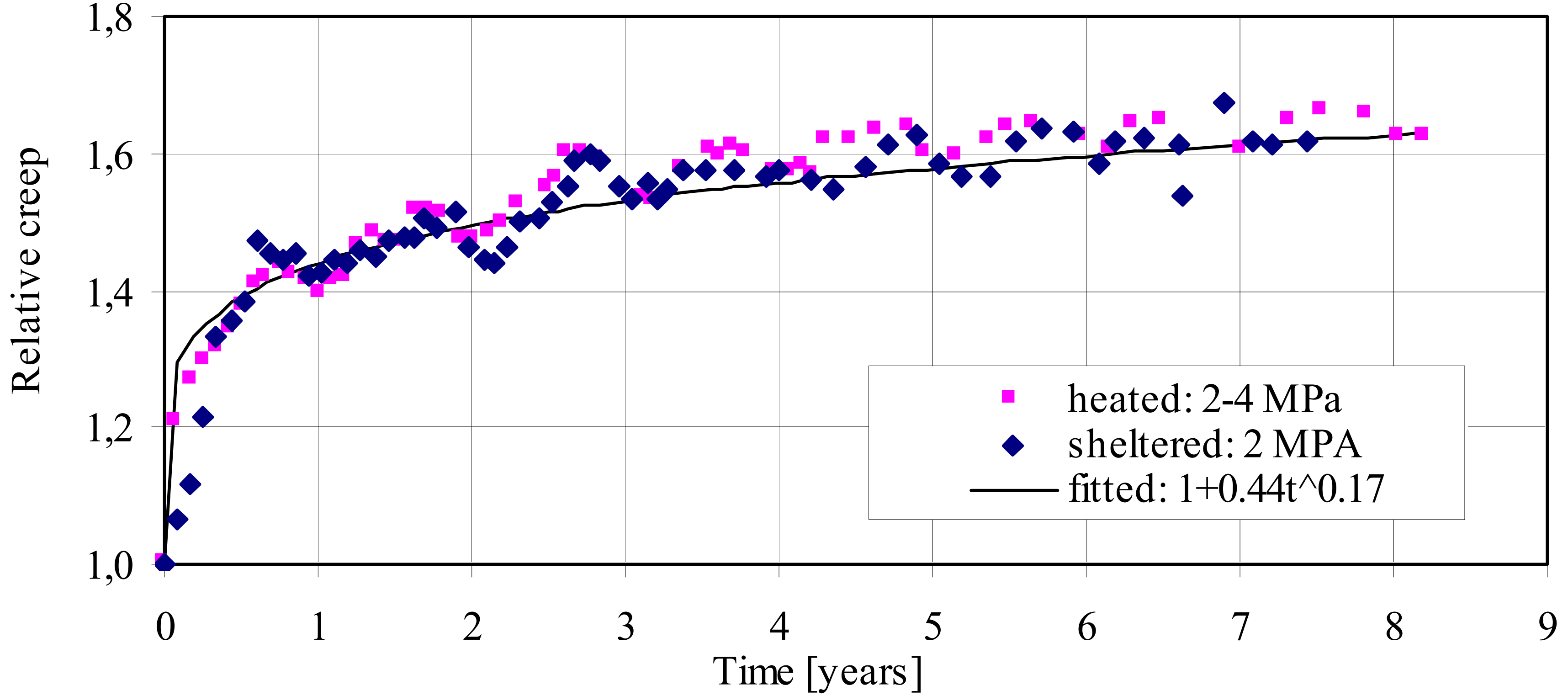
American lumber strength



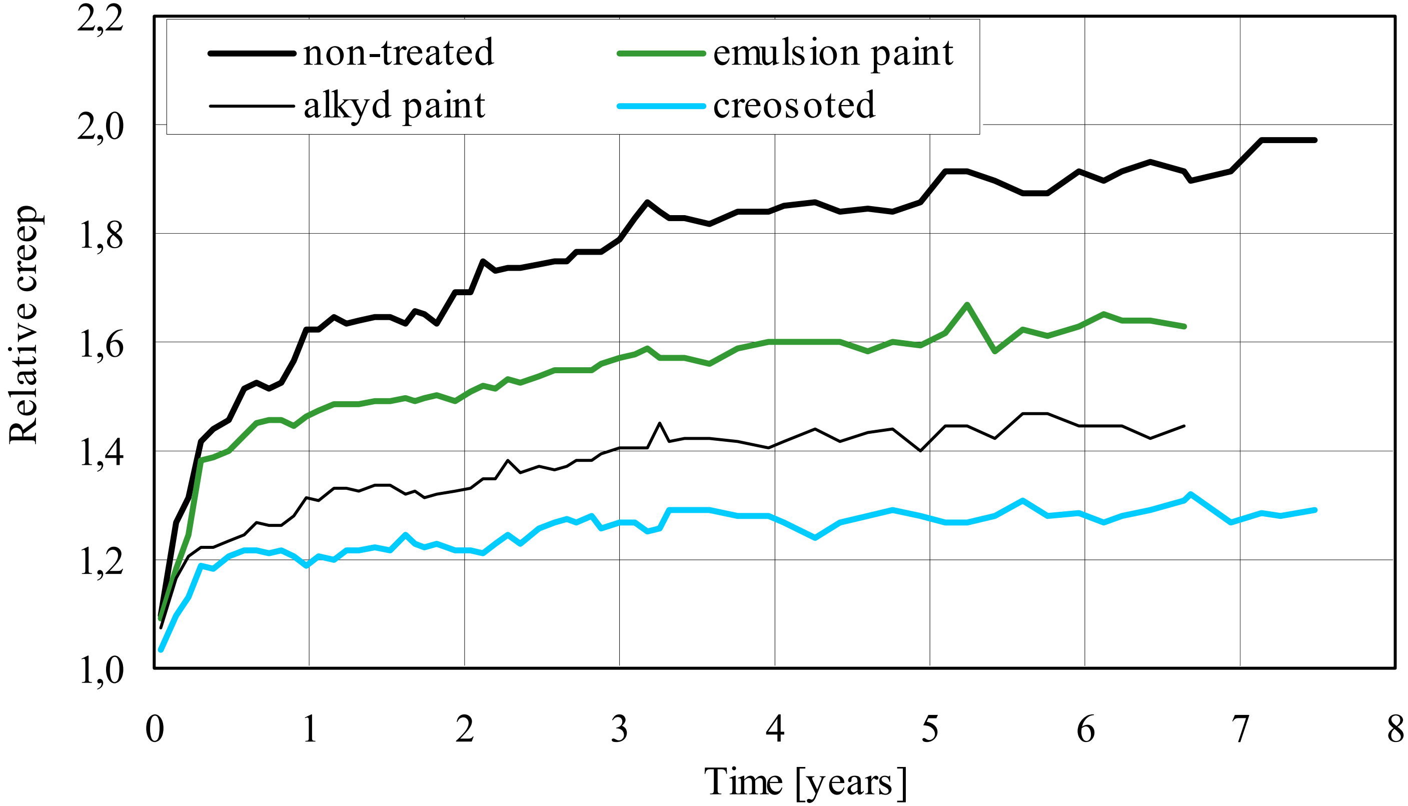
Duration of load effect



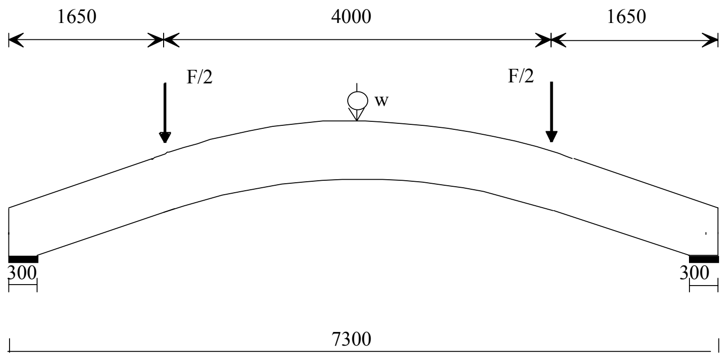
Creep of sawn timber and glulam in heated and unheated room



Effect of treatment on creep in sheltered environment



Duration of load experiments with curved beams



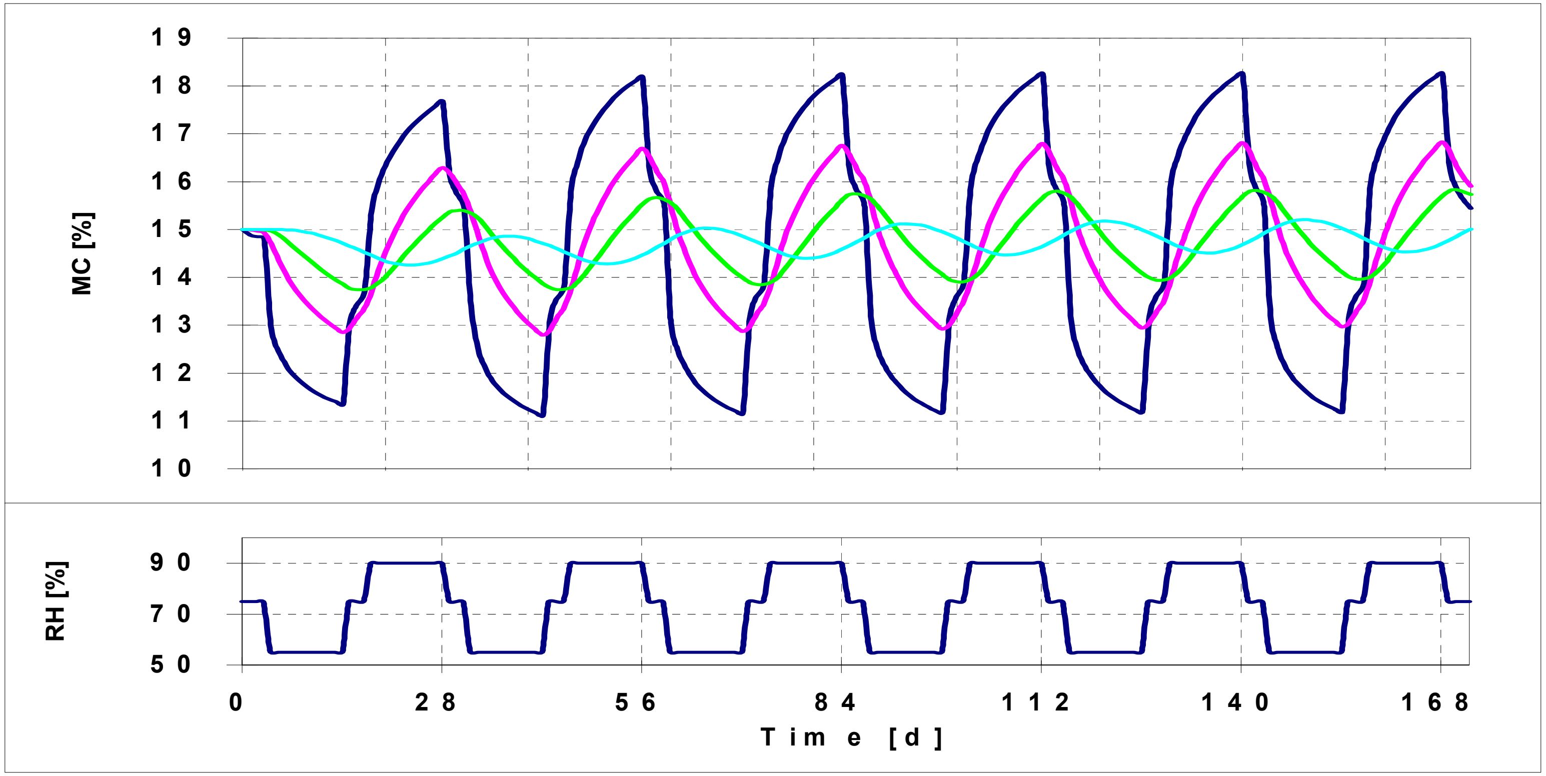
	painted			
RH cycle (%)	40<->85	40<->85	55<->90	55<->90
Width (mm)	90	90	90	140
Time to failure (days)	13	20	28	17
k_{DOL}	0.76	0.55	0.60	0.66

k_{DOL} at constant humidity = 0.8
for 2 to 4 week load duration

Table 4.1 Comparison of DOL- factors obtained in cyclic humidity tests (Aicher et al 1998)

	VTT S2 painted curved beams	VTT S1&3 curved beams	AIR S2 curved beams	AIR S6 curved beams	FMPA small tensile	FMPA small tensile	FMPA large tensile	FMPA large tensile
Conditioning RH (%)	70	70	75	75	65	65	65	65
RH cycle (%)	40<->85	40<->85	55<->90	55<->90	55<->90	natural	55<->90	natural
Width (mm)	90	90	90	140	90	90	140	140
Time to failure (days)	13	20	28	17	18	2.6	19	25
k_{DOL}	0.76	0.55	0.60	0.66	0.45	0.60	0.50	0.64

Moisture is changing in wood



MC at depths of

0 mm

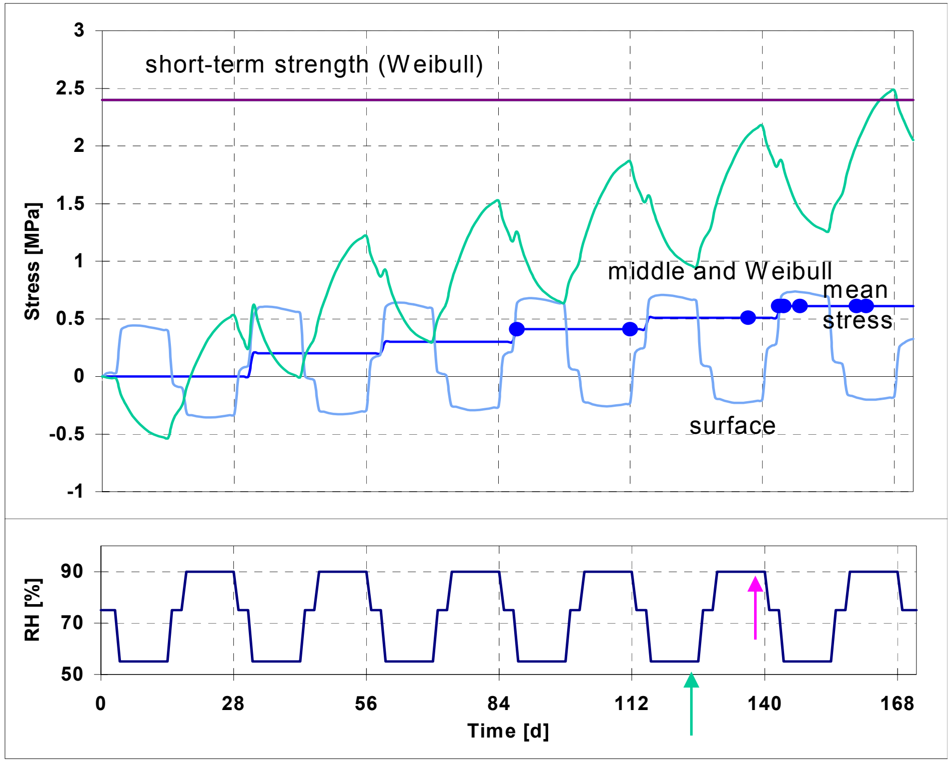
10 mm

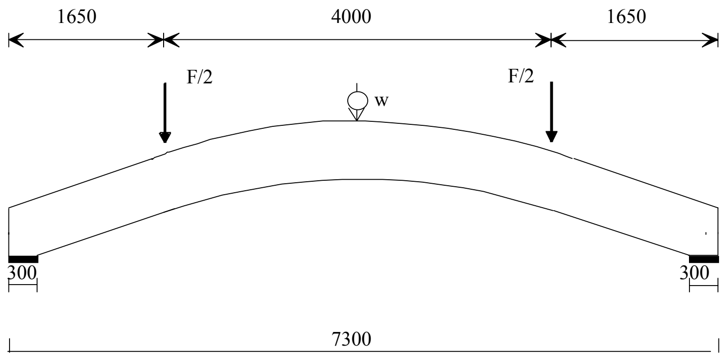
20 mm

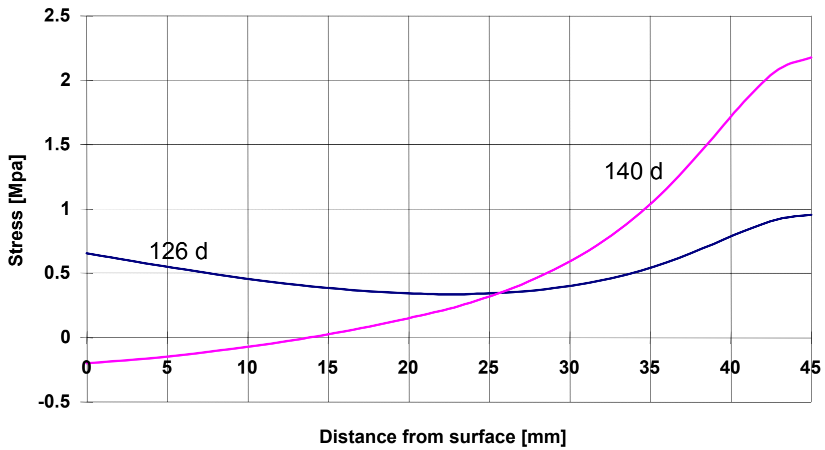
45 mm

Beam thickness
90 mm

Stresses in wood perpendicular to grain







$$\sigma_W = \left(\frac{1}{V_{\text{ref}}} \int_V \sigma_{t,90}{}^k dV \right)^{1/k}$$

Calculated equivalent (mean) stresses for combined moisture and mechanical action for 90 mm thick glulam

Mean stress from external load = **0.20 MPa**

RH cycle	Equivalent stress
65 -> 90 %	**0.52 MPa**
75 -> 90 %	**0.40 MPa**
55 <-> 90 %	**0.45 MPa**
40 <-> 85 %	**0.35 MPa**
40 <-> 85 %	**0.25 MPa surface coated**

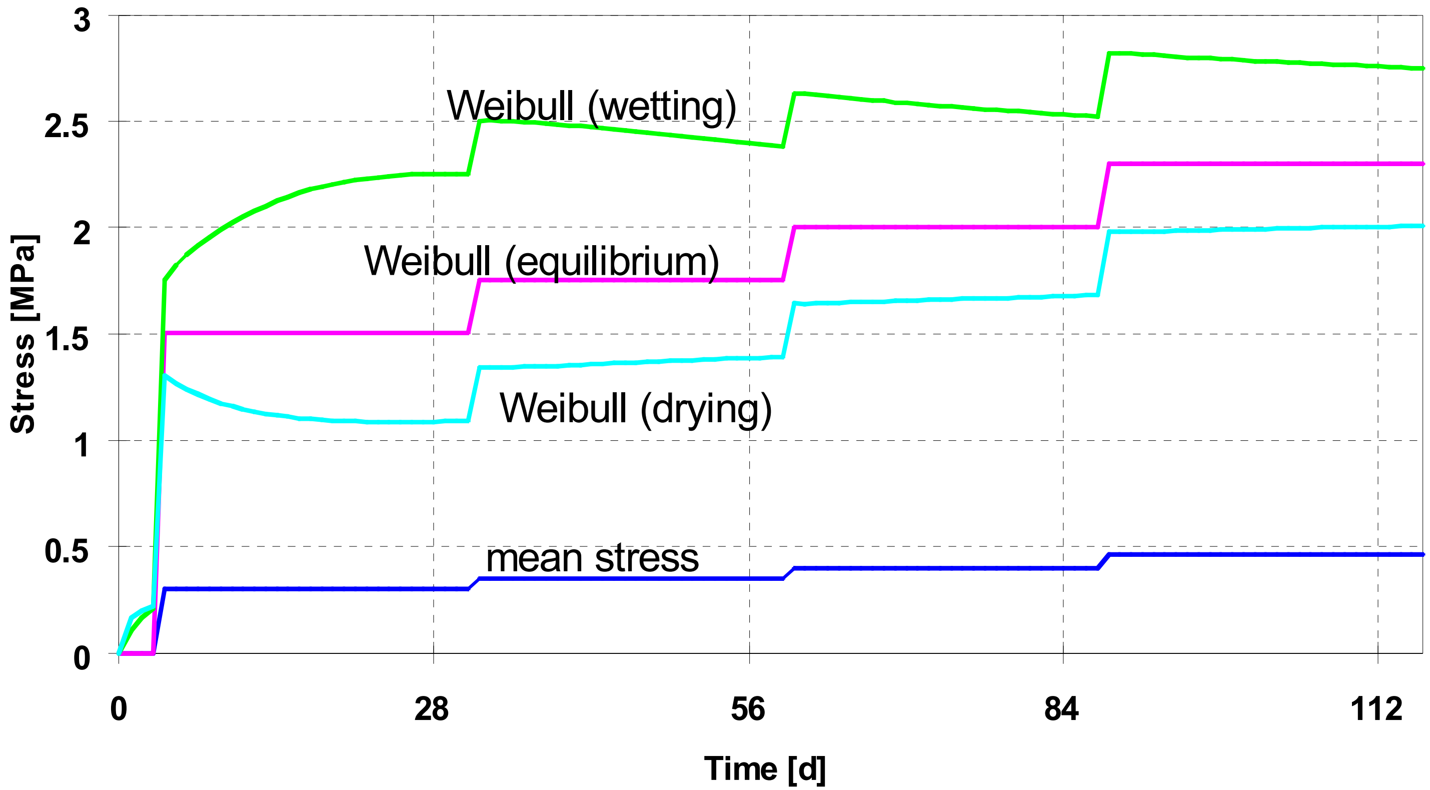
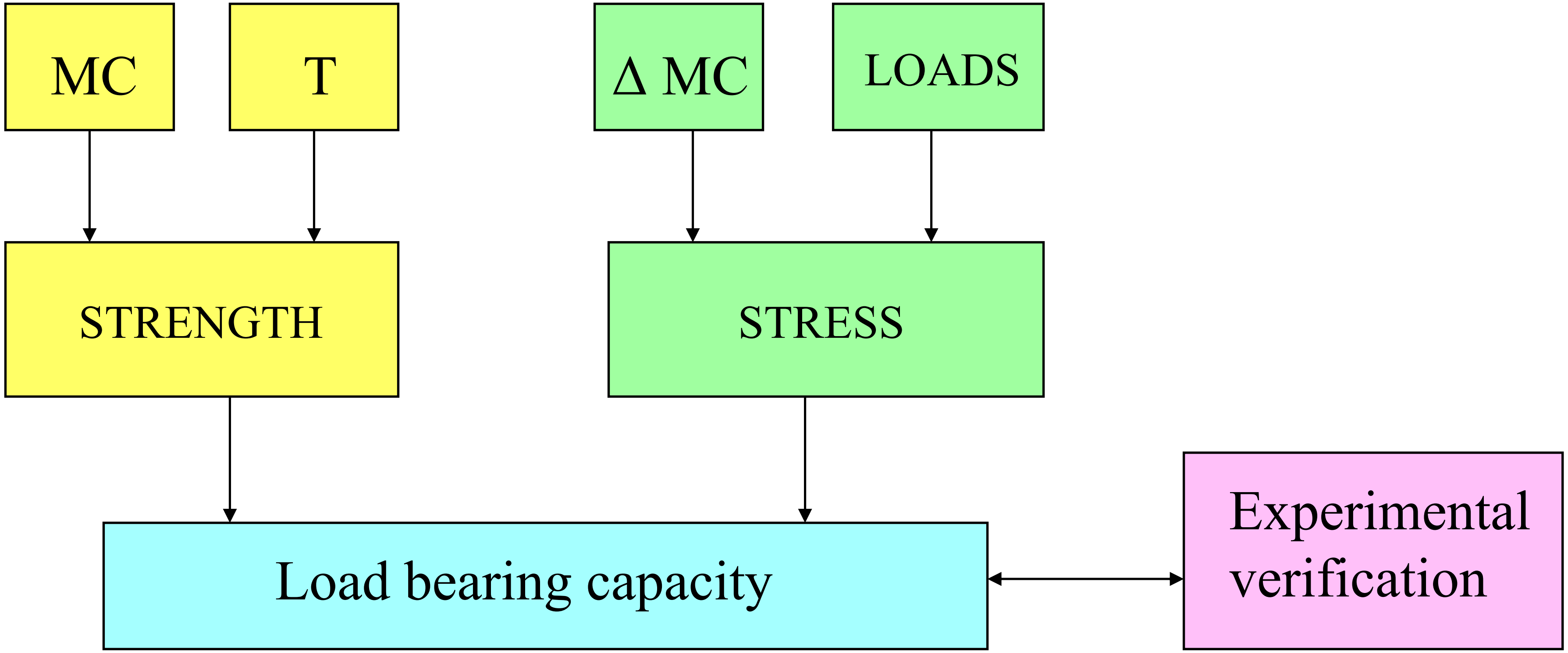
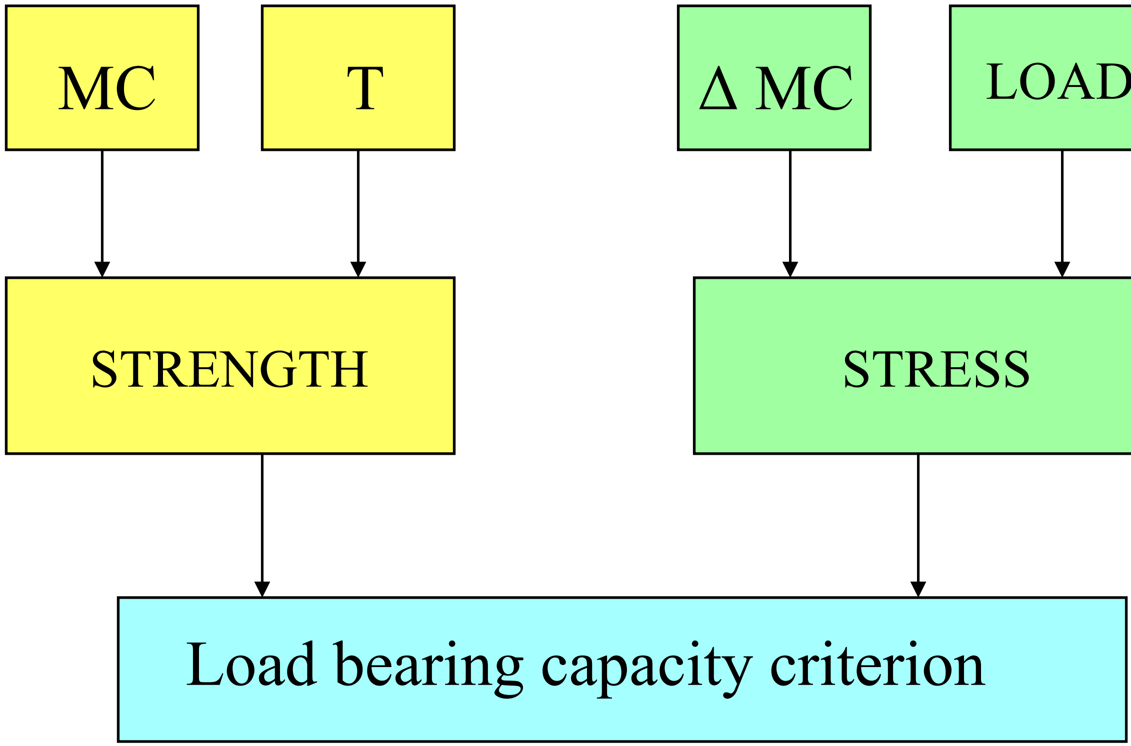


Figure 6.1 Calculated Weibull stresses in 140 mm wide test beams when pre-test conditioning moisture content is the same as during the test or 3% EMC lower or higher (Fig. 57, Gowda et al 1998)


MC
T
Δ MC
LOADS
STRENGTH
STRESS
Load bearing capacity
Experimental verification

Conclusion:
Moisture gradient is an action on structure



$$\gamma_G \sigma_G + \gamma_Q (\sigma_{Q1} + \psi \sigma_{Q2}) \le \frac{k_{\mathrm{mod}} f}{\gamma_M}$$

Consideration of moisture gradients in structural design

- It is suggested that transient moisture conditions resulting in tensile stress perpendicular to grain should be considered as a load case instead of strength reducing factor
- The design equation for multiple loads is expressed in design codes in principle as follows:

$$\gamma_G \sigma_G + \gamma_Q (\sigma_{Q1} + \psi \sigma_{Q2}) \leq \frac{k_{\text{mod}} f}{\gamma_M}$$