Unité Sciences du Bois et des Biopolymères

Université Bordeaux 1 /CNRS/INRA

Modelling load duration of timber beams under various relative humidity conditions

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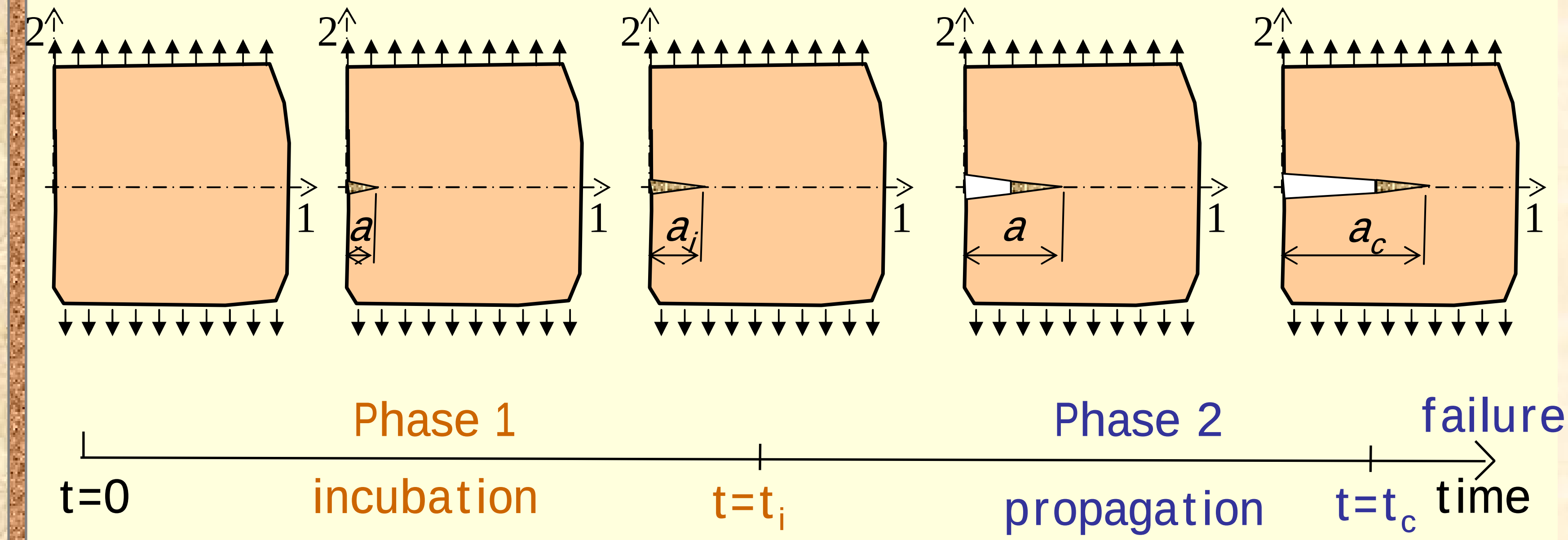
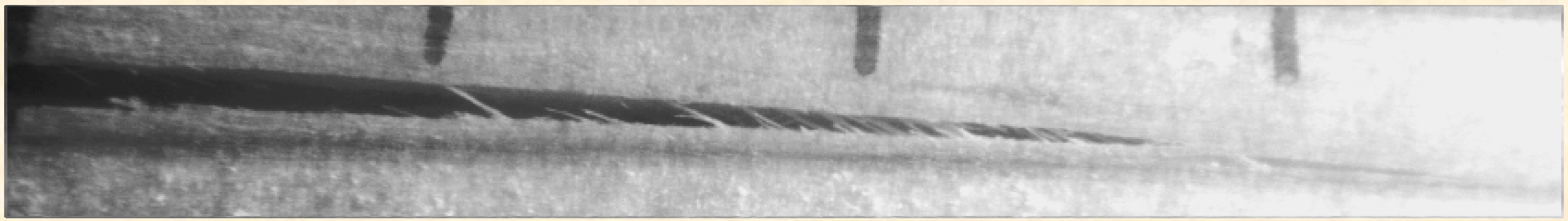
Modelling of the Performance of Timber Structures Eindhoven oct.2007

COST E55 -- 4-5 oct. 2007

Introduction

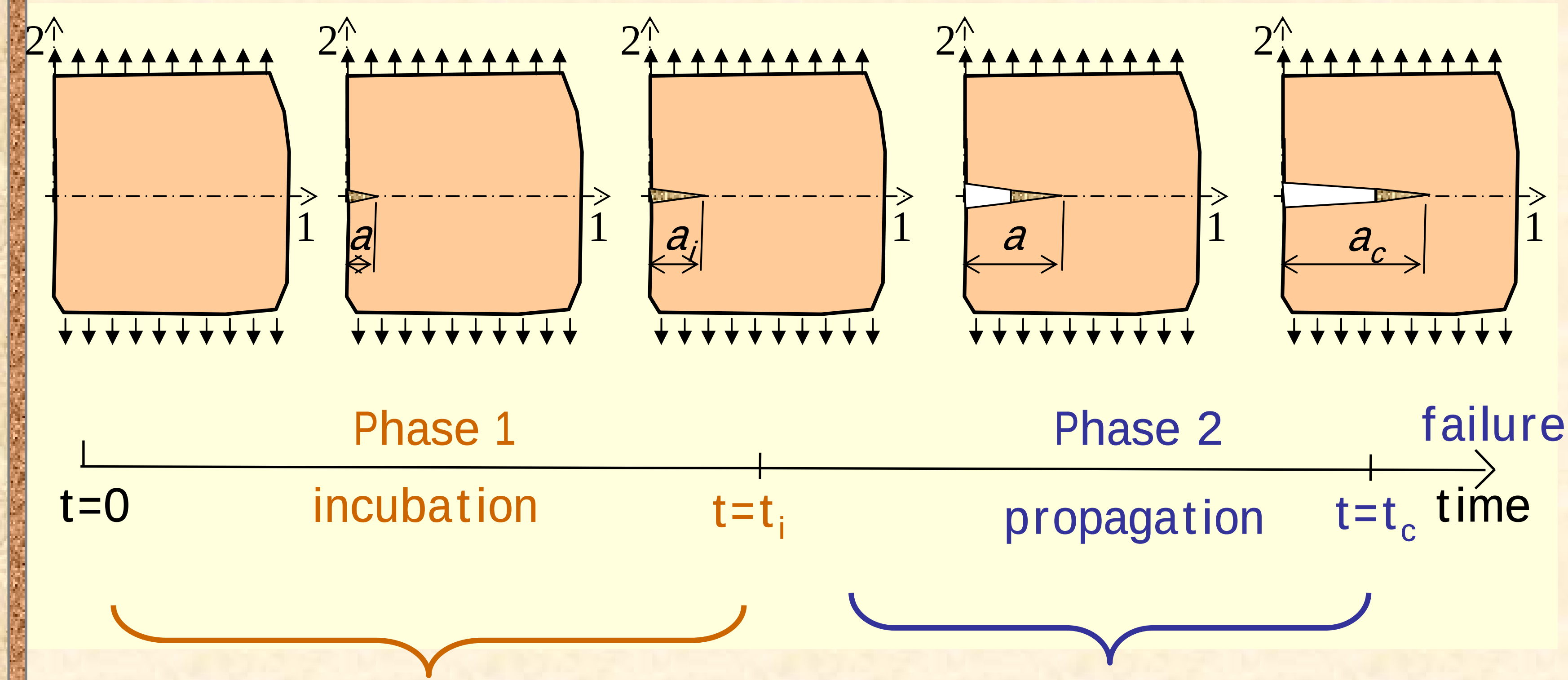
Creep – fatigue loading **(Opening mode)**





Introduction

Creep – fatigue loading **(Opening mode)**



Damage Model **Fracture mechanics model**

VCM **(Viscoelactic Crack Model)**

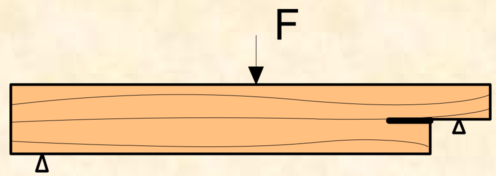
- ☞ Experimental observations
- ☞ Viscoelastic Crack Model (VCM)
- ☞ Predictions / experiments
- ☞ Conclusion /objectives

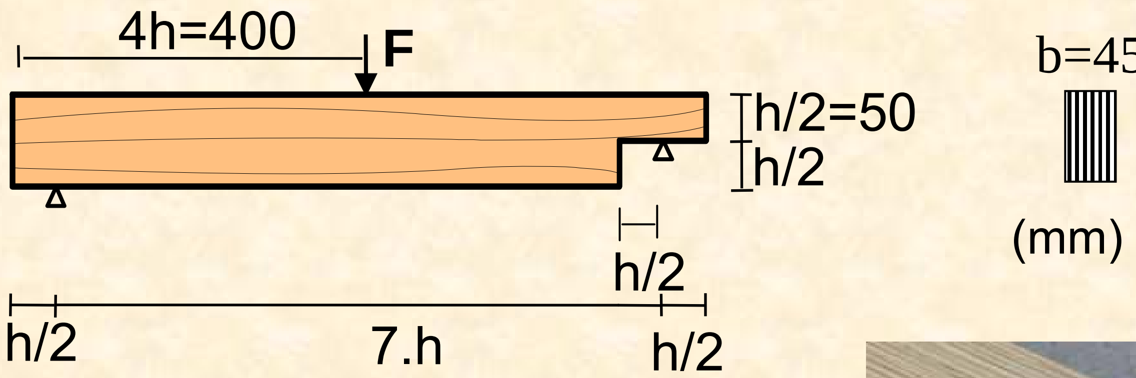
EXPERIMENTAL

OBSERVATIONS

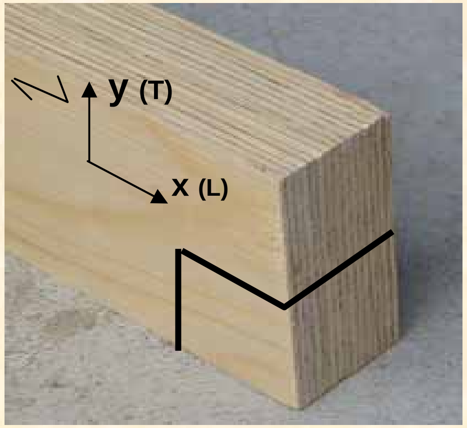
Experimental observations

Experiments **(LVL beams):**



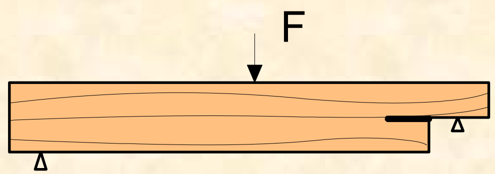


Inside – Outside



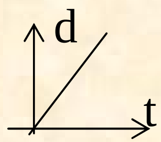
Experimental observations

Experiments **(LVL beams):**



✓**Short term tests**

- ➢ Strength (F_s) $\Rightarrow$ Stress Level SL



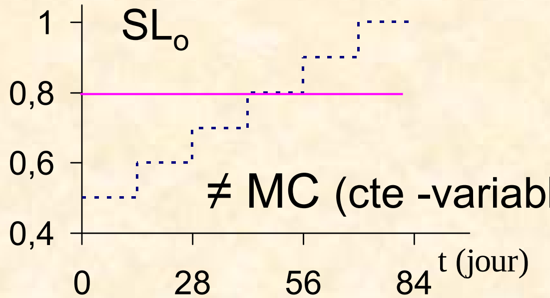
≠ MC (9% - 20%)

$SL = F/F_s$

✓**Long term tests**

- ➢ Incubation time (t_i)
- ➢ Propagation time (t_p)

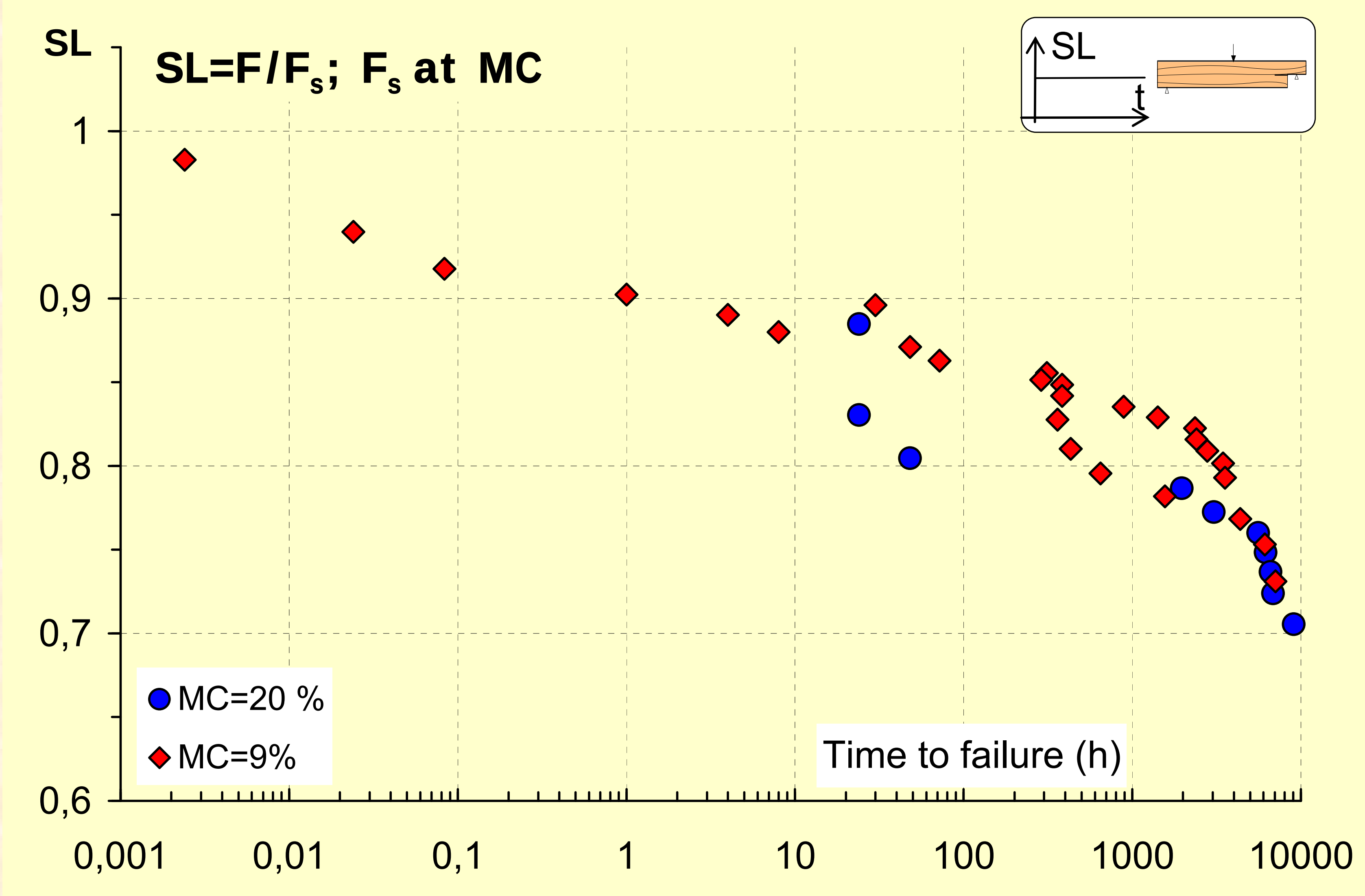
$F = SL_o . F_{so}$



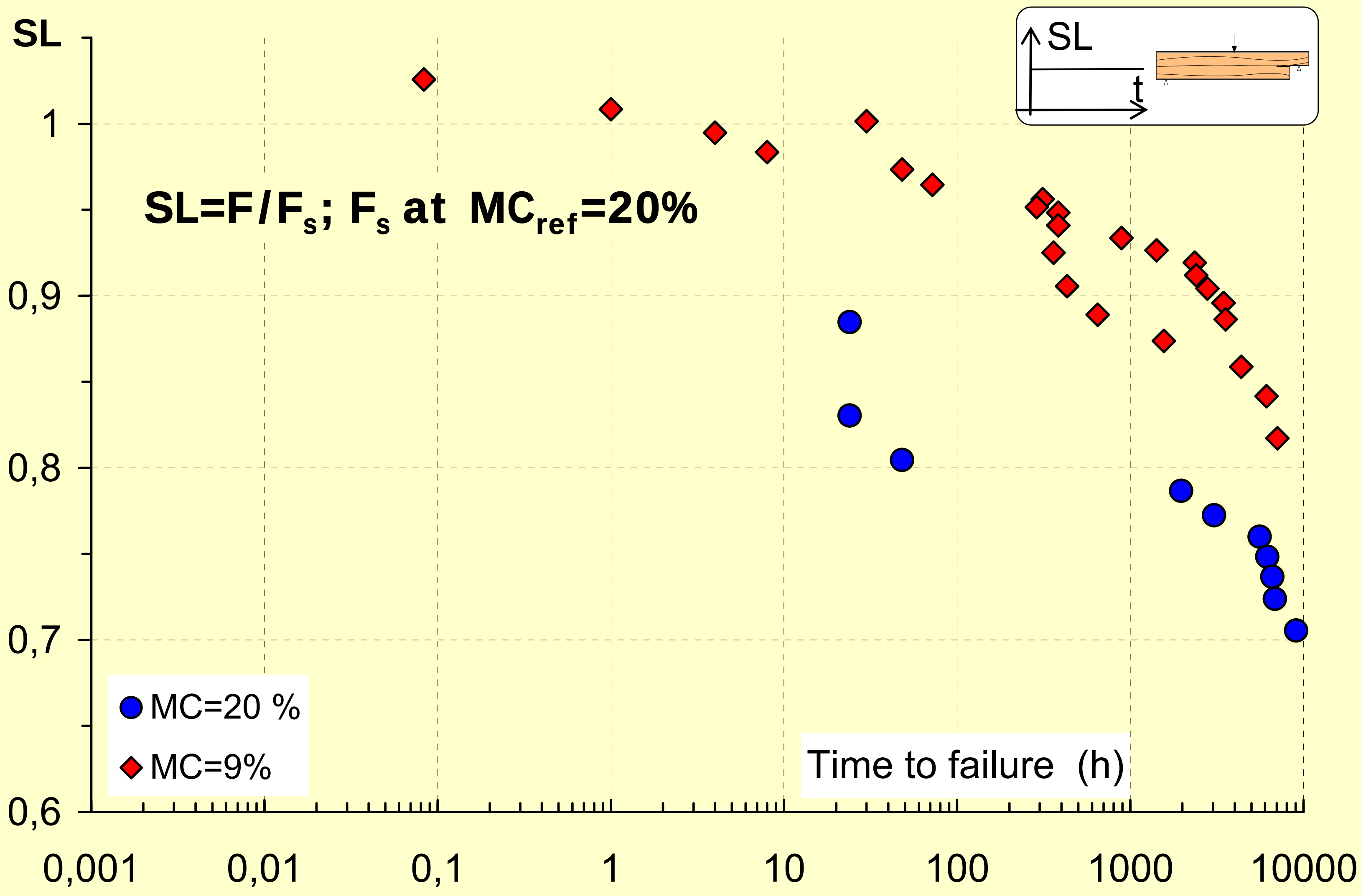
↳**Time to failure (t_r)**

F_{so}= average strength (MC=20%)

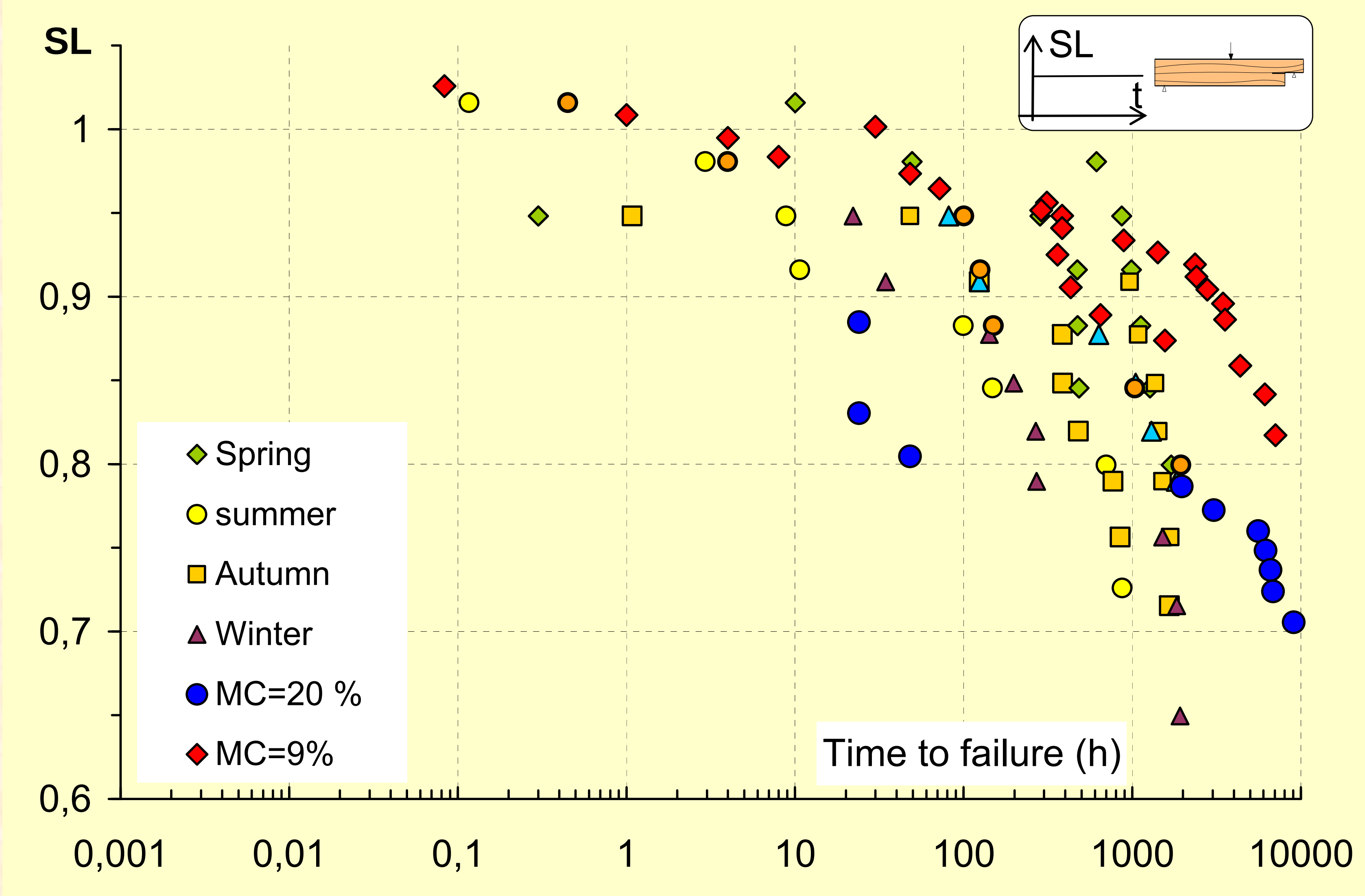
Experimental observations



Experimental observations



Experimental observations



Experimental observations

For a given SL=F/F_s with F_s at MC_{ref}=20% :

- ☞ **Time to failure** **dry≥ wet**
- ☞ **Incubation time** **dry < wet**
- ☞ **Propagation time** **dry > wet**

Viscoelastic

Crack Model

Incubation – Damage modelling

Damage model

$$\begin{cases} \dfrac{dD}{dt} = a.\left(\dfrac{F}{F_s} - \dfrac{F_o}{F_s}\right)^b + c.D & \text{if} \quad F > F_o \\ \dfrac{dD}{dt} = 0 & \text{if} \quad F \leq F_o \end{cases}$$

⚠ F_s : F_s at MC_{ref}=20%

(D : damage parameter)

✓ $t=0 \;\; D=0 \Rightarrow t=t_i \;\; D=D_i$

Notched LVL beam with a process zone = 5 mm

a_i = 5 mm ⇒ **$D_i \approx 0{,}01$** **(Cast3M)**

✓ $F_o/F_s=SL_o$: function of MC

SL_o=0,55 for MC=9% **SL_o=0,60 for MC=20%**

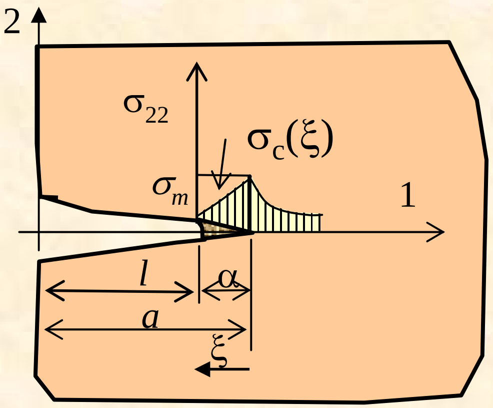
Crack propagation modelling

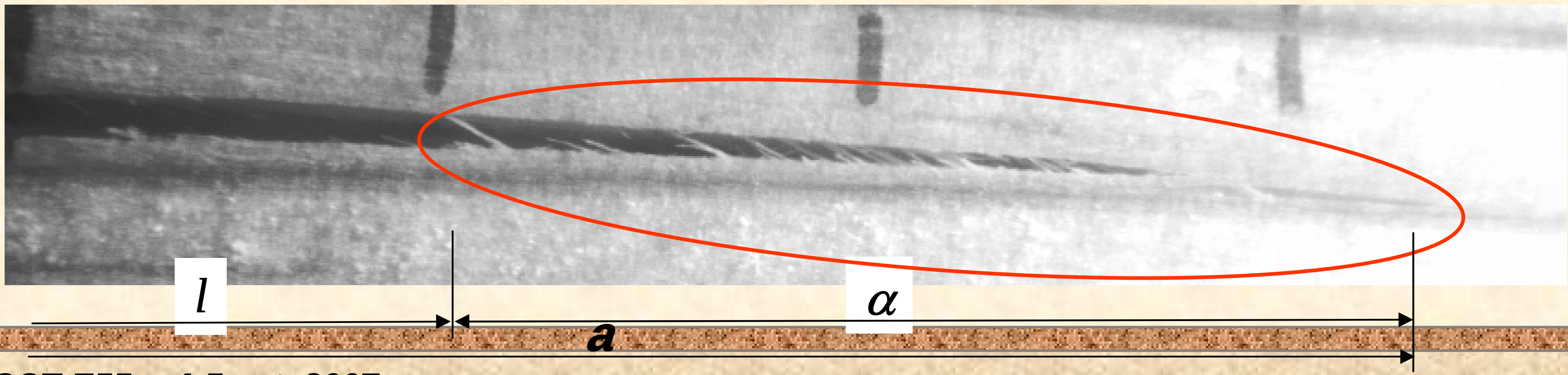
Propagation

$$\frac{da}{dt} = \frac{\pi}{2}\left[\frac{C_2\lambda_n}{\left(K_{Ic}^2 - K_I^2\right)}\right]^{\frac{1}{n}} \frac{K_I^{2\left(1+\frac{1}{n}\right)}}{\left(\sigma_m I_1\right)^2}$$

☞ *σ_m, I_1 (function of MC)*

$$\sigma_m = \underset{0<\xi<\alpha}{Max}\left(\sigma_c(x)\right) \qquad I_1 = \int_0^{\alpha}\left[\frac{\sigma_c(\xi)}{\sigma_m}\frac{1}{\sqrt{\alpha.\xi}}\right]d\xi$$





Crack propagation modelling

Propagation $$\frac{da}{dt} = \frac{\pi}{2}\left[\frac{C_2\lambda_n}{\left(K_{Ic}^2 - K_I^2\right)}\right]^{\frac{1}{n}} \frac{K_I^{2\left(1+\frac{1}{n}\right)}}{\left(\sigma_m I_1\right)^2}$$

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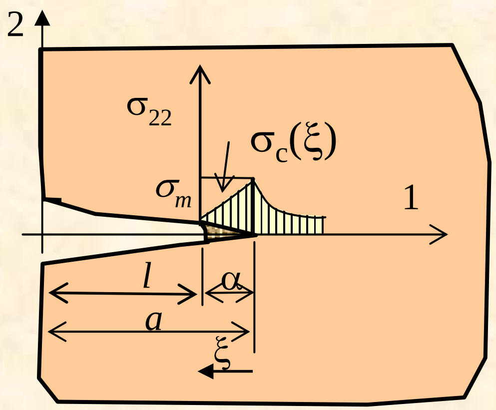

☞ **Reduced compliance** $\kappa^v(t) = C_o(1 + C_2 t^n)$ *(function of MC)*

$$\lambda_n = 3\sqrt{\pi}\,\Gamma(n+1)/[4(n+3/2)\Gamma(n+3/2)] \text{ avec } \Gamma(n) = \int_0^\infty t^{n-1}e^{-t}dt$$ (function gamma)

Crack propagation modelling

Propagation

$$\frac{da}{dt} = \frac{\pi}{2}\left[\frac{C_2 \lambda_n}{\left(K_{Ic}^2 - K_I^2\right)}\right]^{\frac{1}{n}} \frac{K_I^{2(1+\frac{1}{n})}}{(\sigma_m I_1)^2}$$

☞ **Stress intensity factor**

$$K_I(a) = \frac{F}{b\sqrt{w}} g(a/w)$$

(*b* : thickness - *w* : characteristic dimension of the specimen)

g : calibration function depending on MC

Crack propagation modelling

Propagation $$\frac{da}{dt} = \frac{\pi}{2}\left[\frac{C_2\lambda_n}{\left(K_{Ic}^2 - K_I^2\right)}\right]^{\frac{1}{n}} \frac{K_I^{2(1+\frac{1}{n})}}{(\sigma_m l_1)^2}$$

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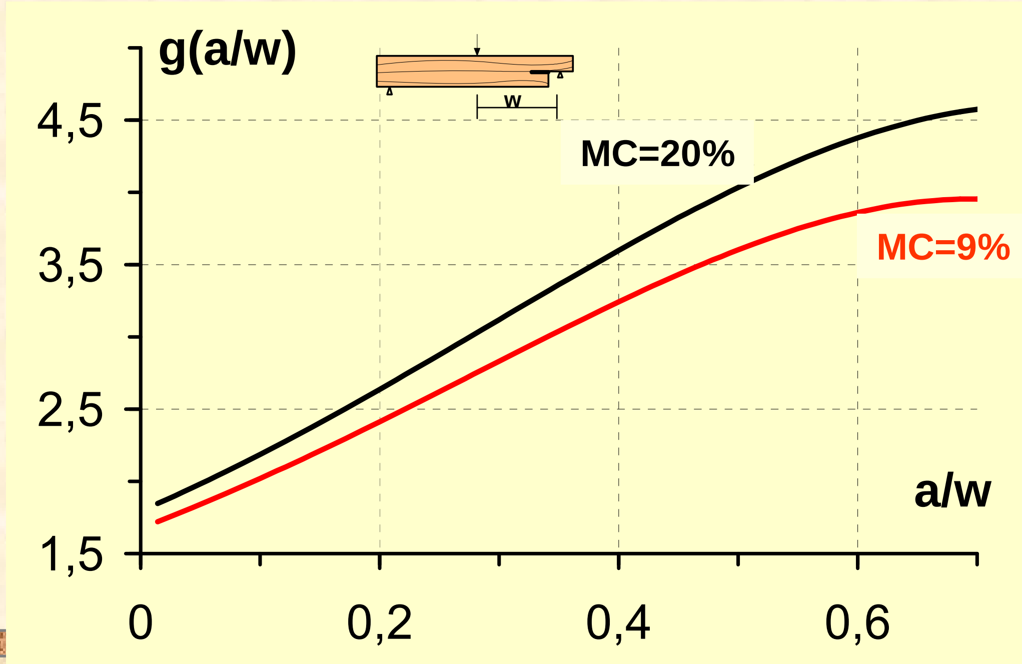

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☞ **Stress intensity factor** $$K_I(a) = \frac{F}{b\sqrt{w}} g(a/w)$$

(*b* : thickness - *w* : characteristic dimension of the specimen)

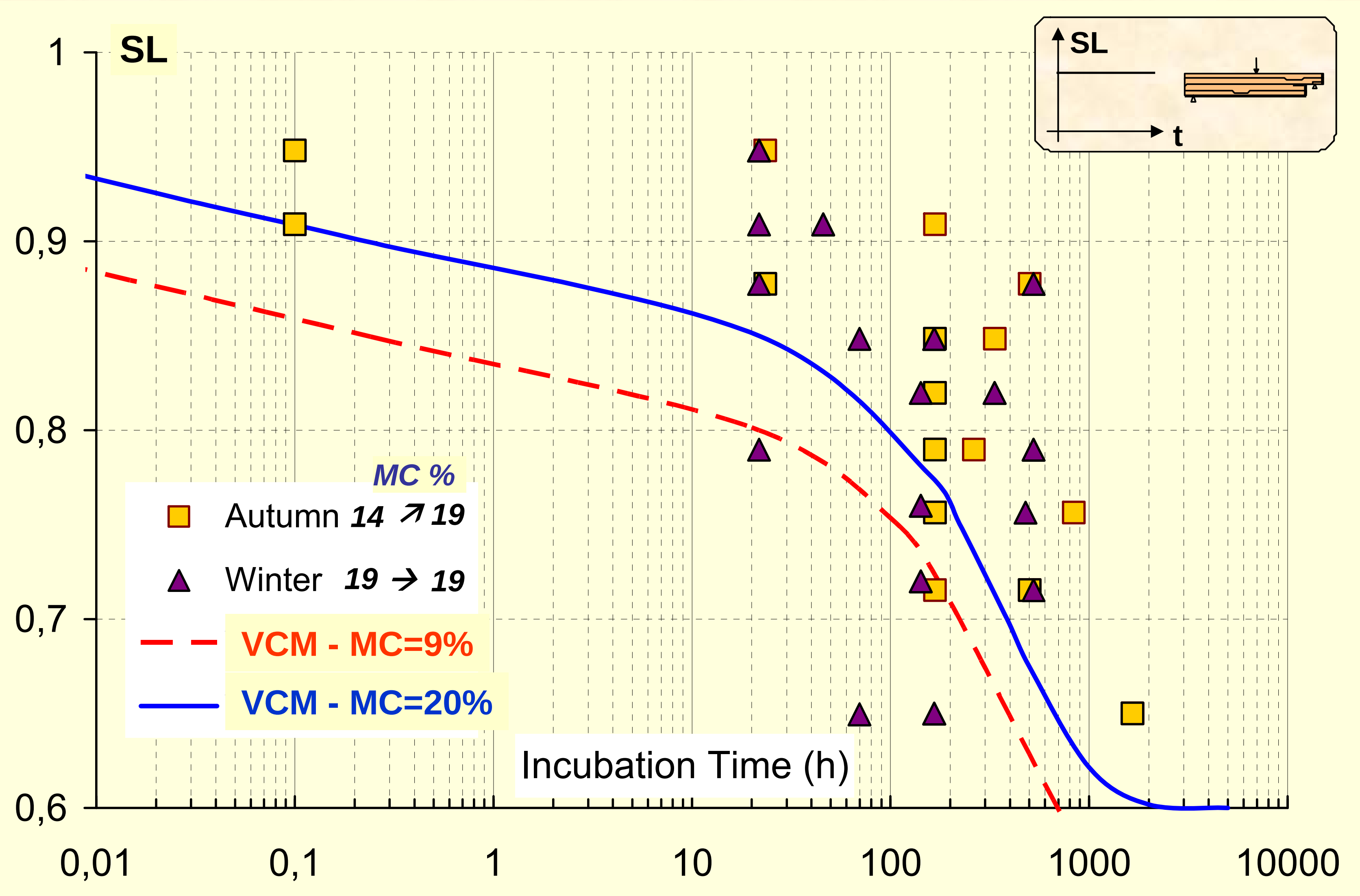
g : calibration function depending on MC

Failure $K_I = K_{Ic} = \sqrt{2G_I / C_o}$

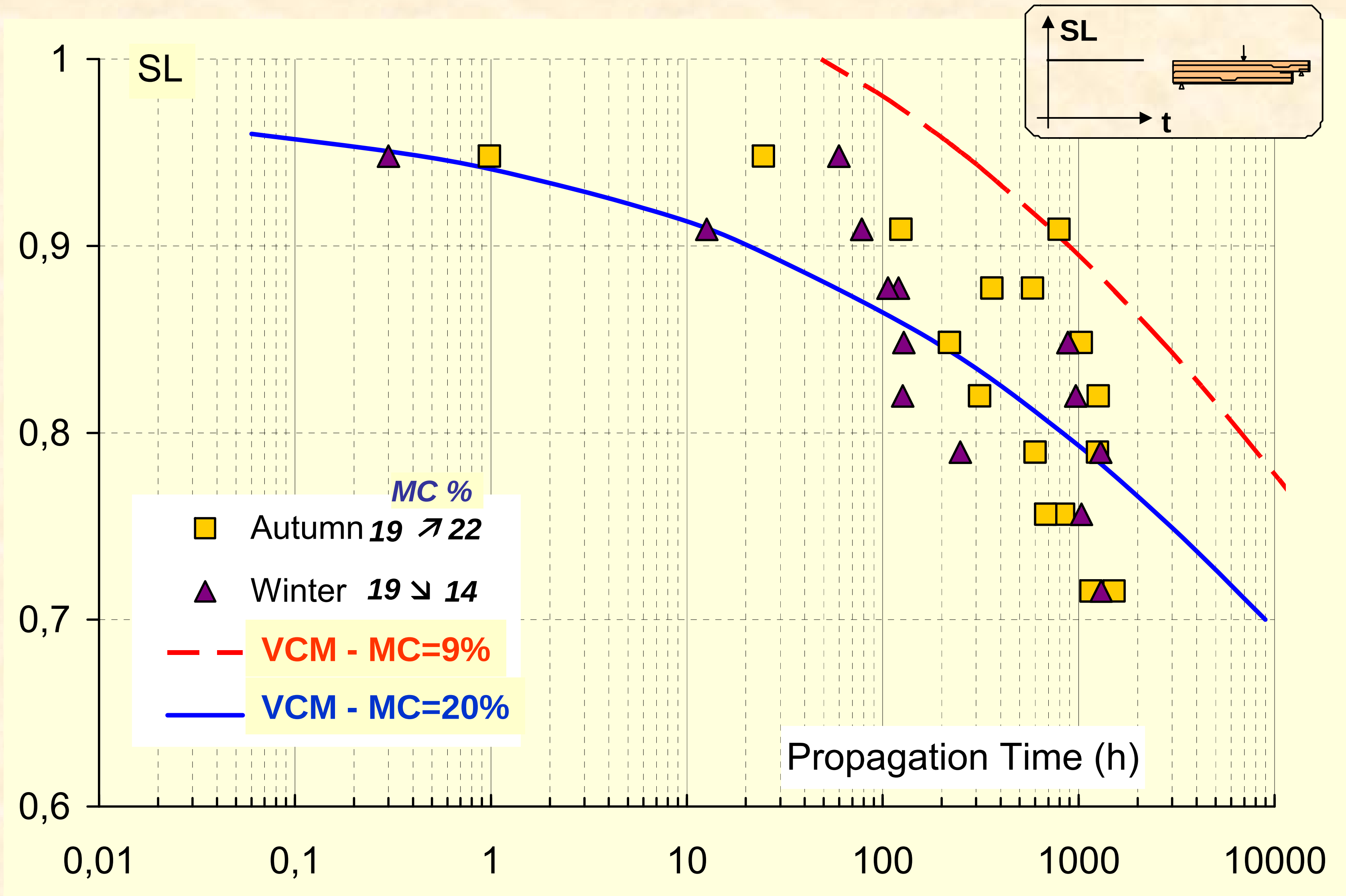
G_I : Fracture energy *(not depending on MC)*

Predictions
vs
experiments

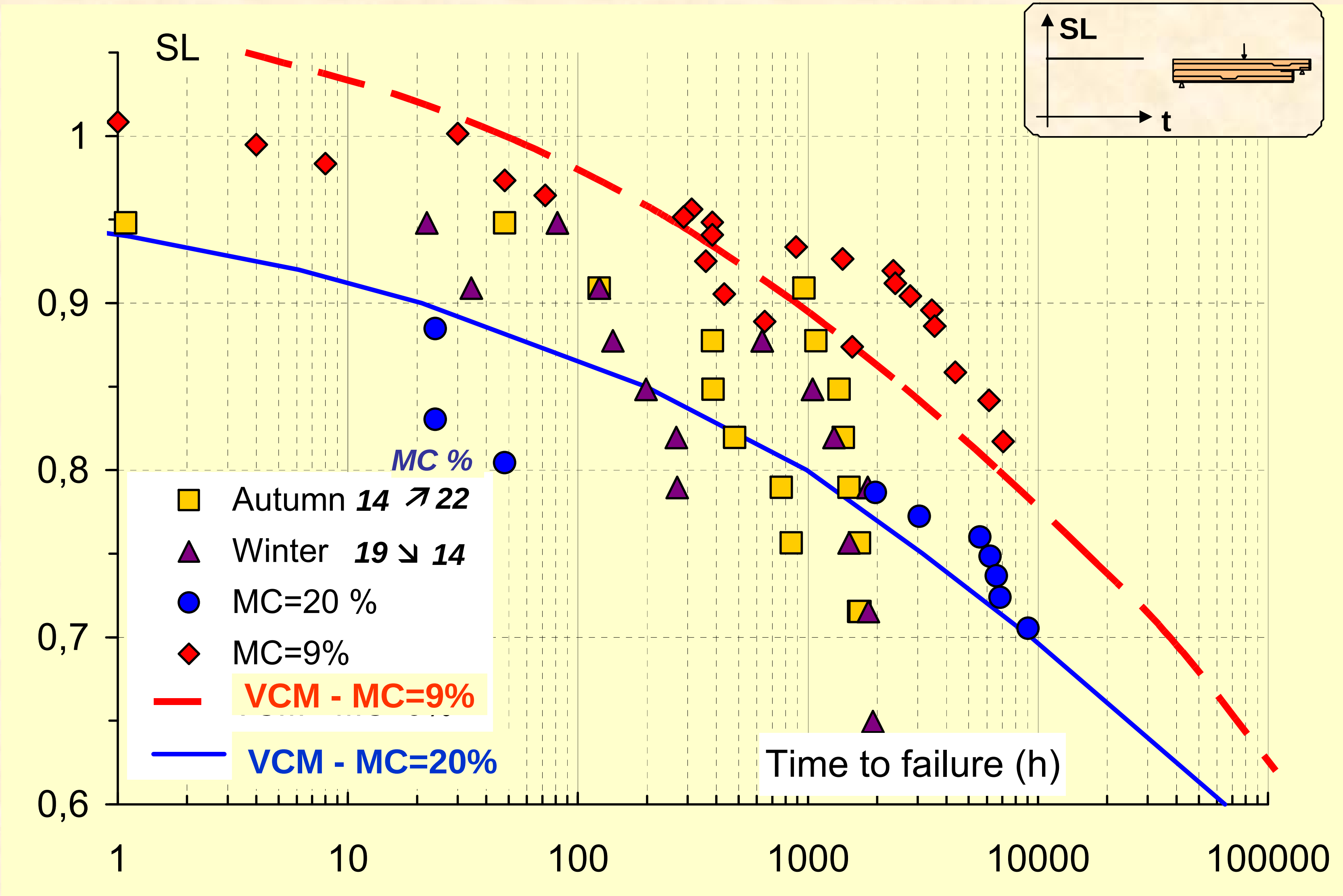
Incubation time



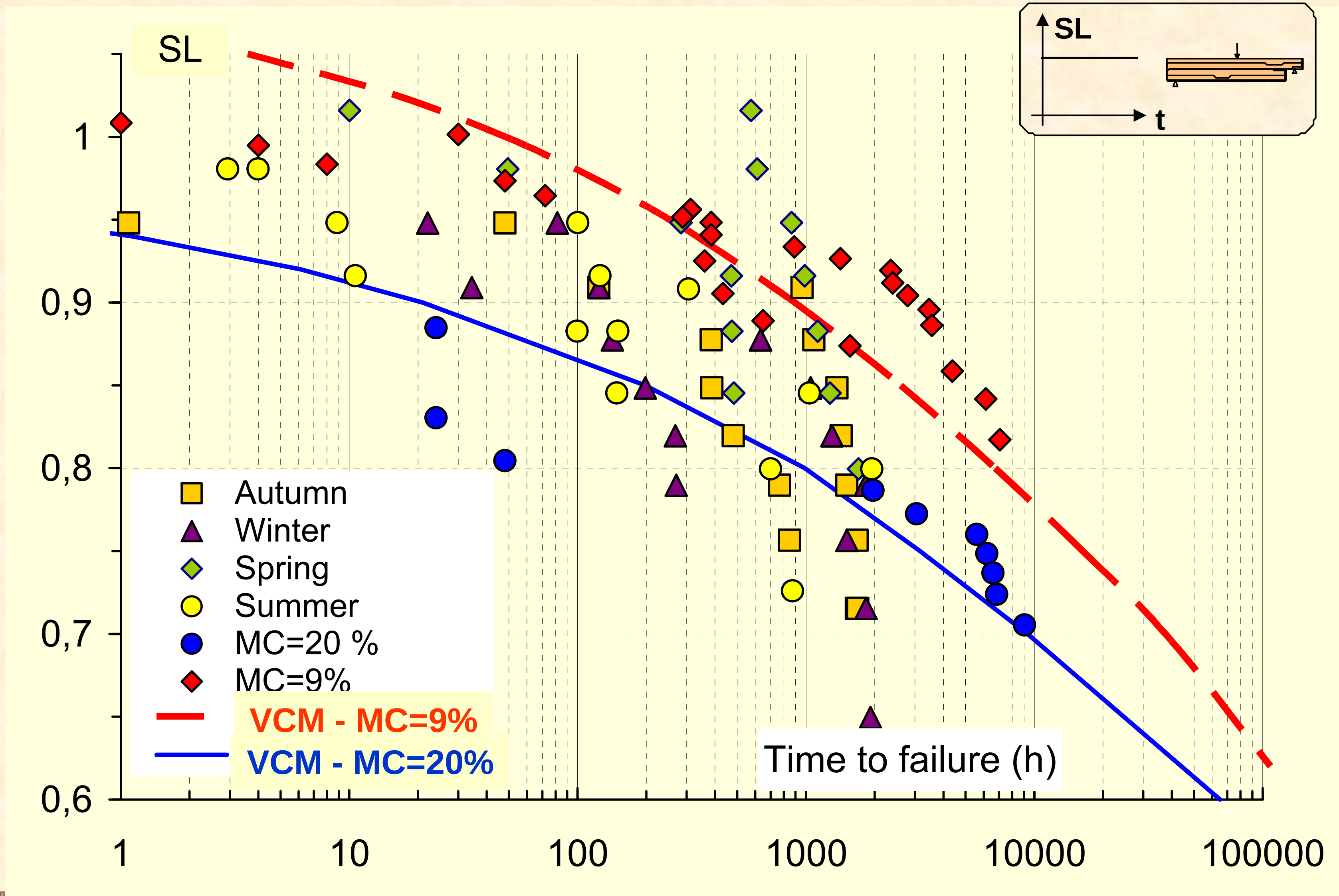
Propagation time



Time to failure



Time to failure



Conclusion

✓ **Influence of relative humidity:**

- ☞ **Incubation time** dry < wet
- ☞ **Propagation time** dry > wet
- ☞ **Time to failure** dry ≥ wet

(Scattering of experimental results)

✓ **Delayed Fracture VCM:**

- ☞ **Incubation : damage model**
- ☞ **Propagation : NLEF model**

} **Time to failure**

Under stabilized MC

Objectives

- ✓ **Introduce MC change effects into VCM**
- ✓ **Modelling climate scenarios**

  (Probabilistic approach) : (HR, T°) → MC

Connection with the WG2 actions

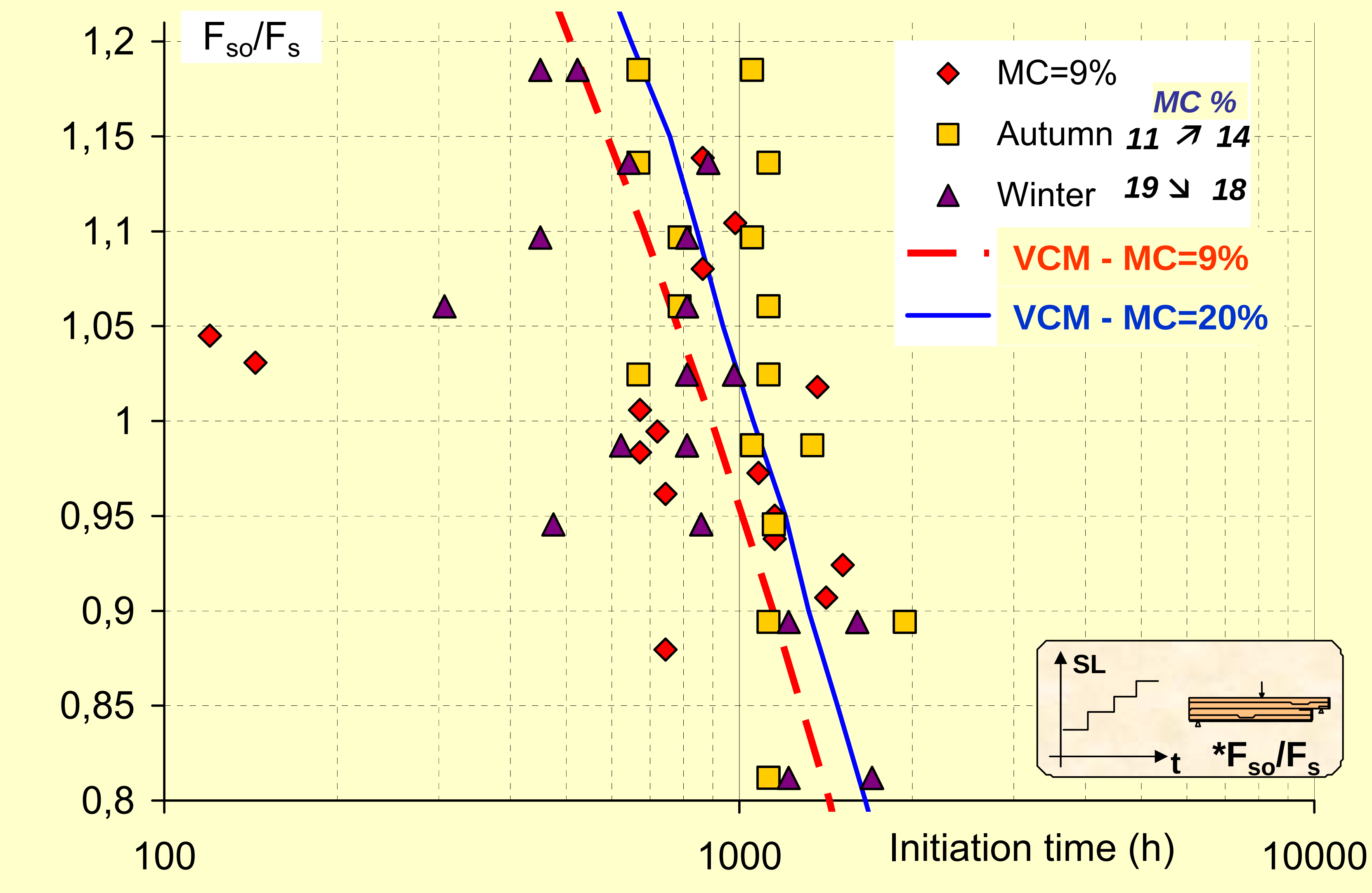
☞**lifetime of timber structure elements**

✓“Dependency climate scenarios which might occur during the lifetime of the structure”

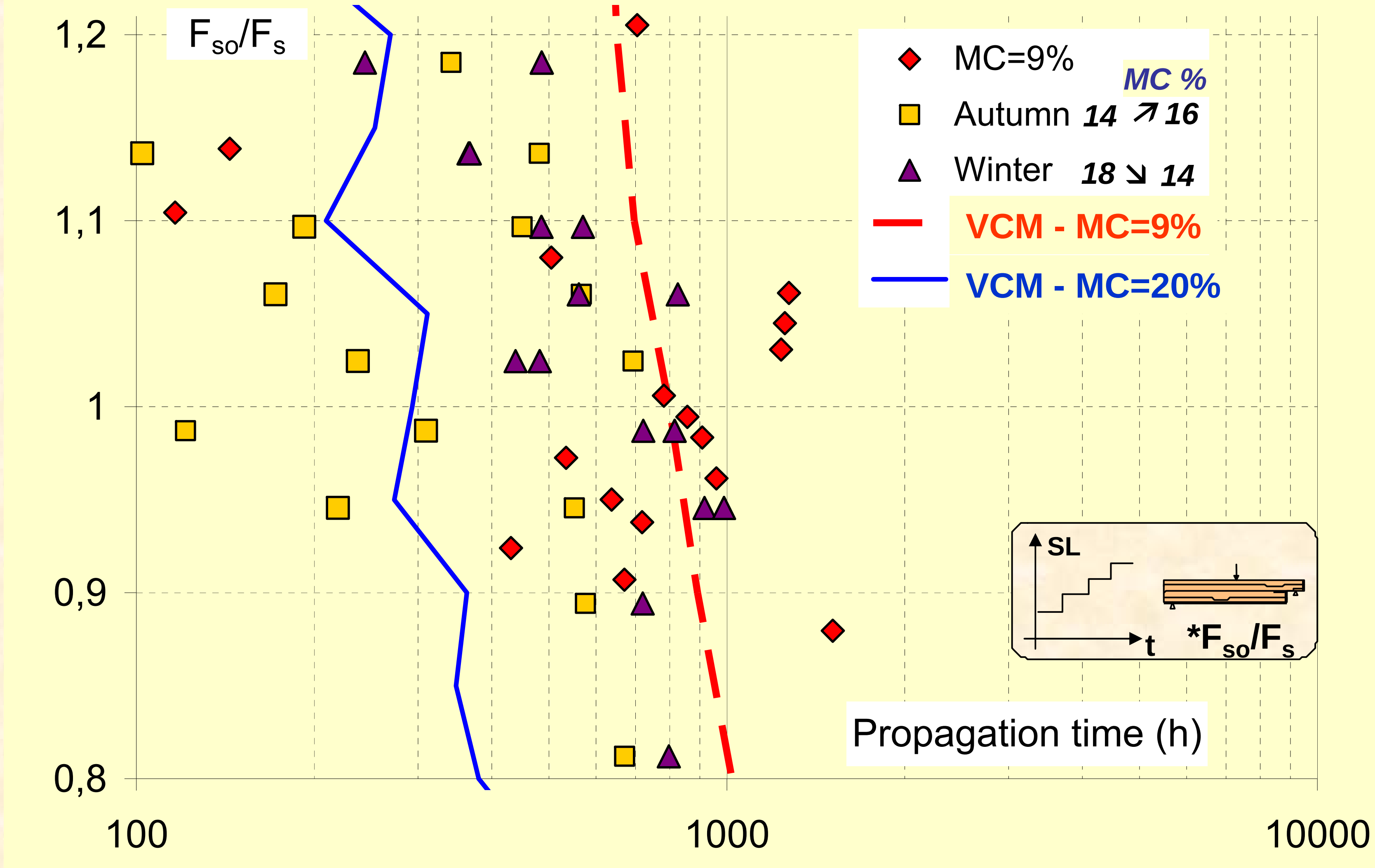
✓“Modelling of moisture-related degradation and service-life assessment of timber components”

THE END

Incubation time



Propagation time



Time to failure