
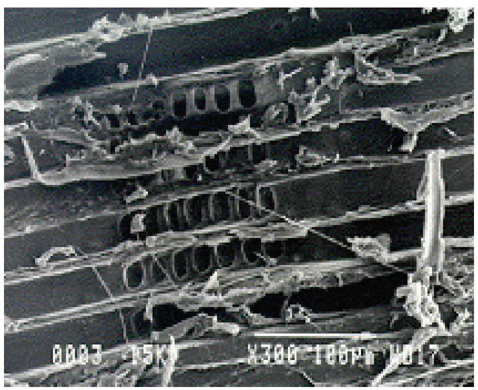

# Evaluation of Moisture Caused Risks in Building Structures

## Buildings XIII Workshop

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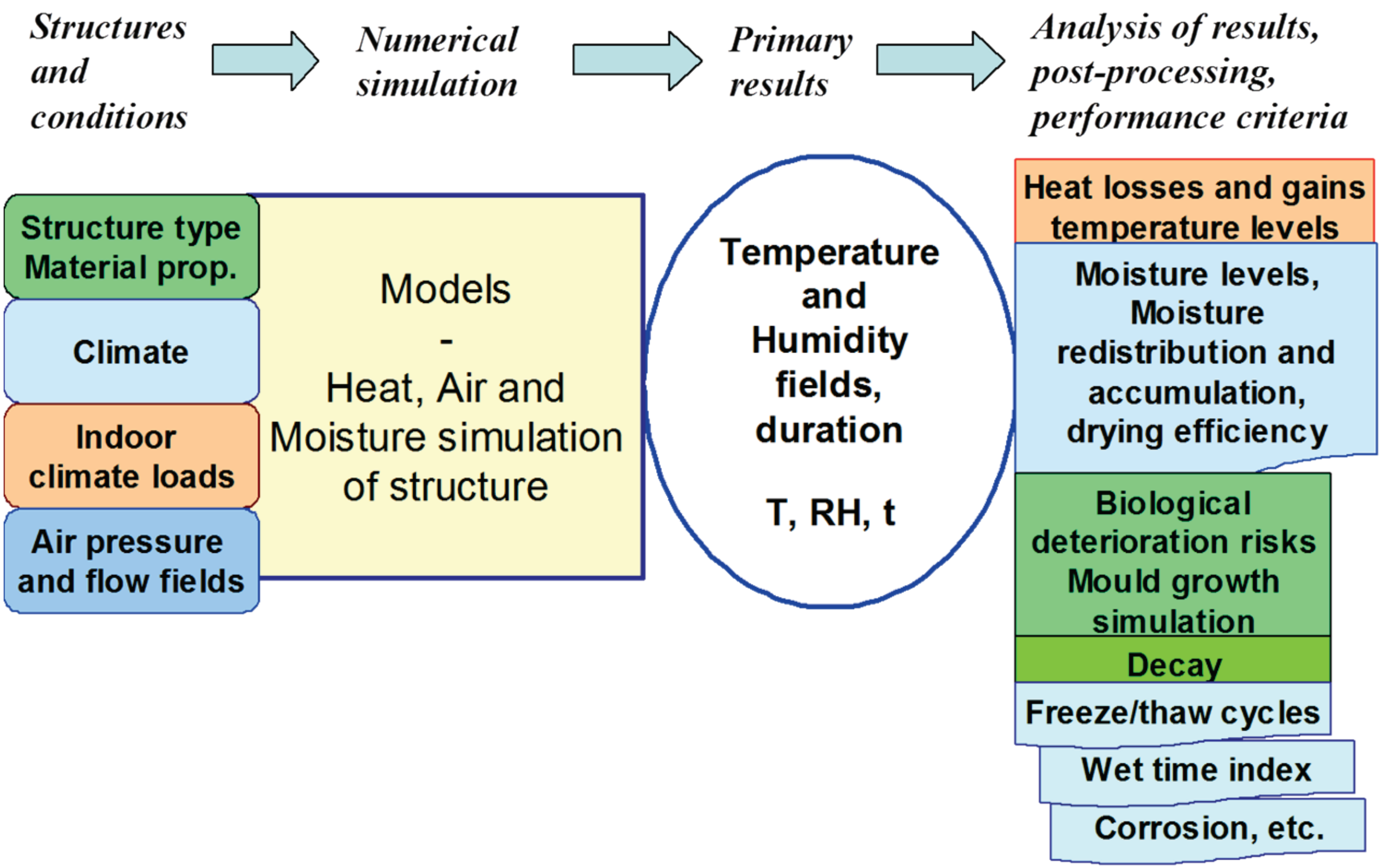
# Contents

- Primary simulation results
- Performance criteria evaluation
- Aspects: Indoor air/Building users, Structures
- Mold
- Decay
- Corrosion

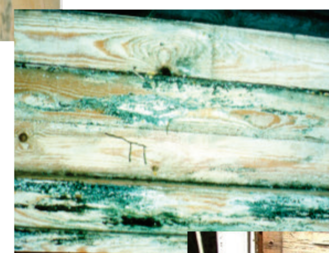
# How to evaluate moisture caused risks in building structures



# Ageing - biological deterioration - damages

- natural ageing
  - grey wood
    - mould
      - indoor air
      - VOCs
      - structure aesthetics
        - load exceeds tolerance
          - decay
            - damage

Service life of buildings



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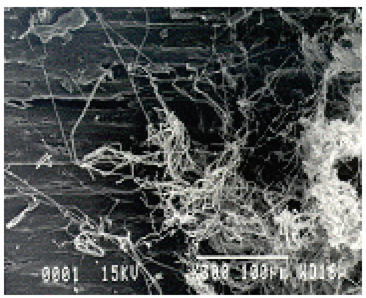
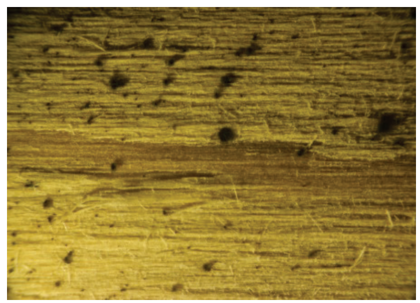
# Mold growth risk analysis

- Mold growth is one of the first signs of too high moisture content in (building) materials
- It may affect the indoor air quality and the appearance of the surfaces

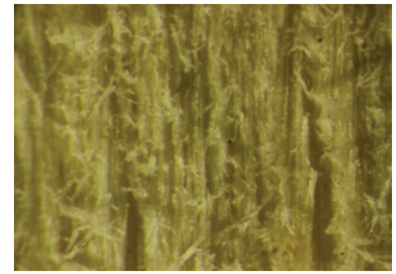


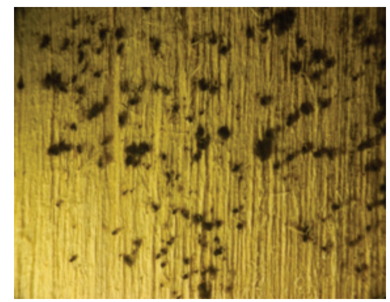


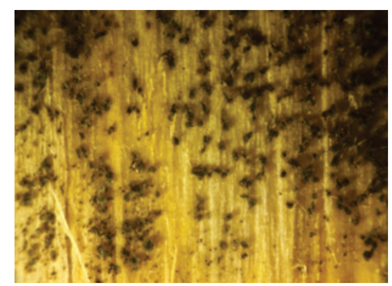
- **Mold does not** cause structural damages (unlike decay), changes only the appearance

# Mold Index – Visual findings presented as growth index values

| Index | Description of the growth rate |
|---|---|
| 0 | No growth |
| 1 | Small amounts of mould on surface (microscope), initial stages of local growth |
| 2 | Several local mould growth colonies on surface (microscope) |
| 3 | Visual findings of mould on surface, < 10 % coverage, or, < 50 % coverage of mould (microscope) |
| 4 | Visual findings of mould on surface, 10 - 50 % coverage, or, >50 % coverage of mould (microscope) |
| 5 | Plenty of growth on surface, > 50 % coverage (visual) |
| 6 | Heavy and tight growth, coverage about 100 % |







# VTT Mold Model - Solver for Mold index

$$\frac{dM}{dt} = \frac{1}{7 \cdot \exp(-0.68 \ln T - 13.9 \ln RH + 0.14W - 0.33SQ + 66.02)} k_1 k_2$$

$$k_1 = \begin{cases} \dfrac{t_{M=1,pine}}{t_{M=1}}, \text{when } M < 1 \\ 2 \cdot \dfrac{(t_{M=3,pine} - t_{M=1,pine})}{(t_{M=3} - t_{M=1})}, \text{when } M \geq 1 \end{cases}$$

$$k_2 = \max\left[1 - \exp\left[2.3 \cdot (M - M_{max})\right], 0\right]$$

$$M_{max} = A + B \cdot \frac{RH_{crit} - RH}{RH_{crit} - 100} - C \cdot \left(\frac{RH_{crit} - RH}{RH_{crit} - 100}\right)^2$$

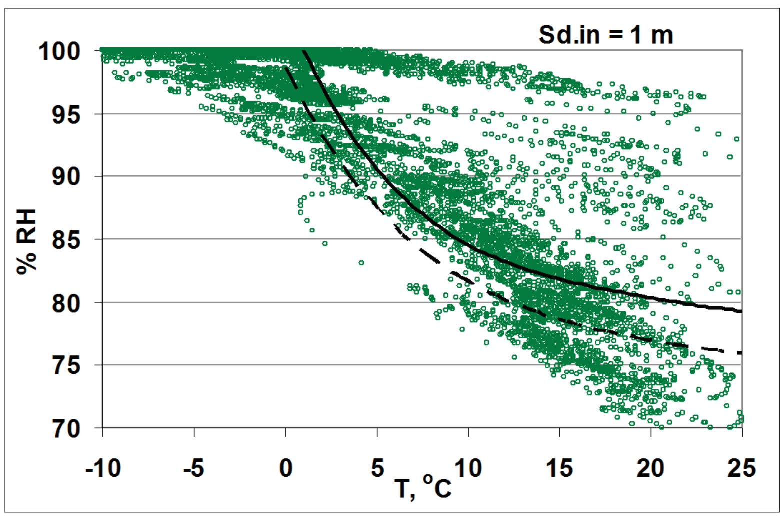
***Scaling factors $k_1$ and $k_2$ for different materials***

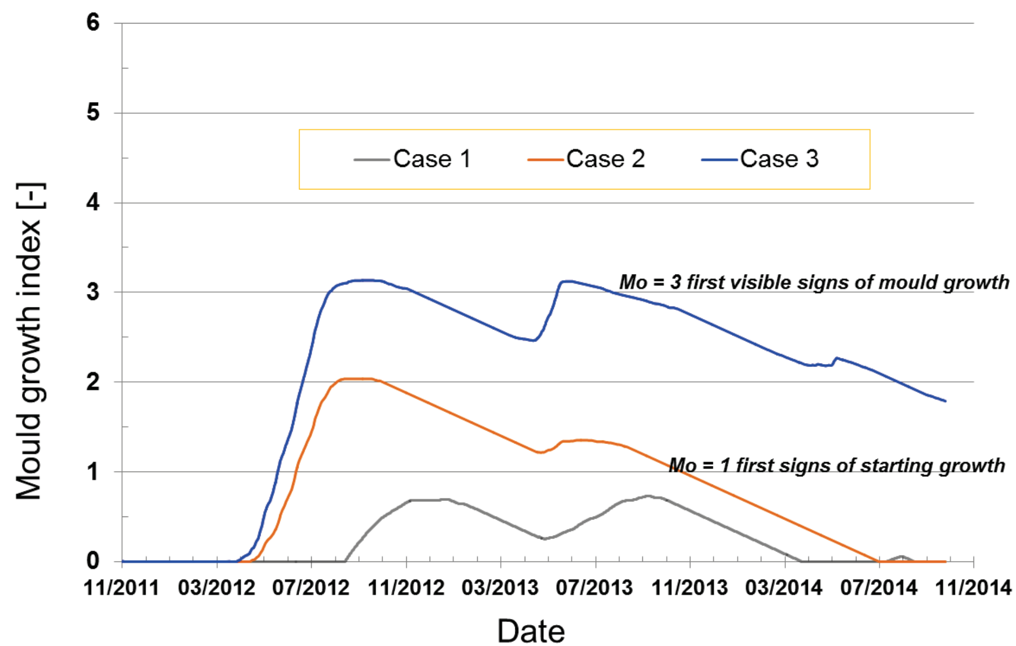
***Coefficient $k_1$ is used to scale the growth intensity***

***Coefficient $k_2$ to limit the growth to maximum possible index level***

# Mold growth risk analysis

- Solved or measured temperature and relative humidity values
- Long period conditon history with 1 h time steps if possible
- Numerical evaluation of Mold index at critical boundary



# Decay of wooden structures – Numerical model

Two parameters:
Activation time $\alpha$
and
Mass loss

$$Activation\ process\ \alpha = 0..1$$

$$\alpha(t) = \int_0^t d\alpha = \sum_0^t (\Delta\alpha)\ ,where$$

$$\Delta\alpha = \frac{\Delta t}{t_{crit}(RH,T)}$$ Under favorable conditions

$$Mass\ loss\ process\ when\ \alpha \geq 1$$

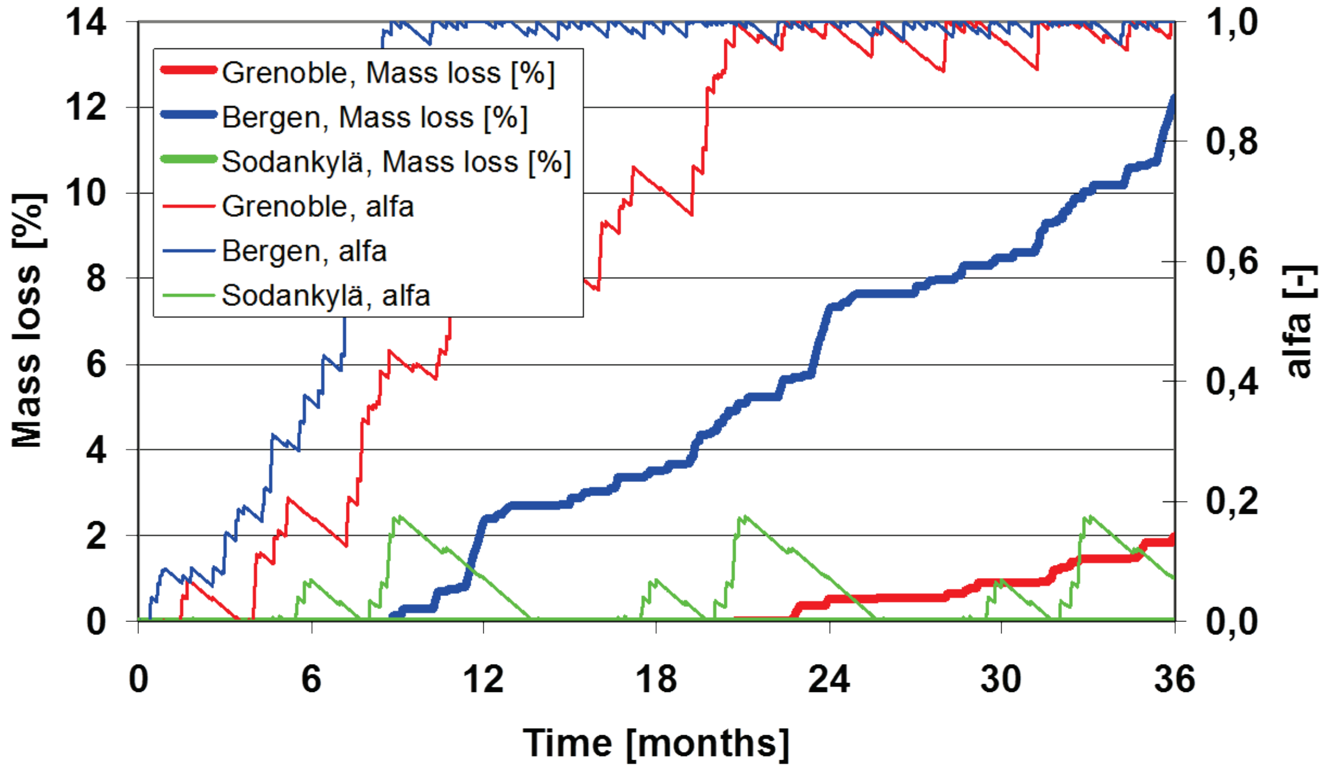
$$ML(t') = \int_{t\ at\ \alpha=1}^{t'} \frac{ML(RH,T)}{dt} dt = \sum_{t\ at\ \alpha=1}^{t'} \left( \frac{ML(RH,T)}{dt} \times \Delta t \right)$$

$$\frac{(RH,T)}{dt} = -5.96\times10^{-2} + 1.96\times10^{-4} T + 6.25\times10^{-4} RH\ [\%/hour]$$

Based on studies by Hannu Viitanen & al. at VTT

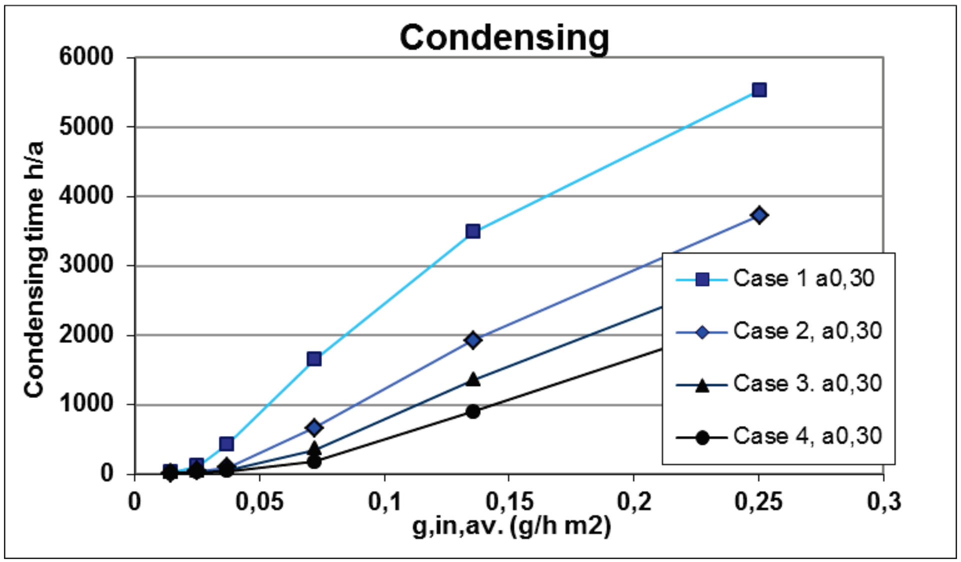
# Decay development in wooden facade during 3 years in different locations

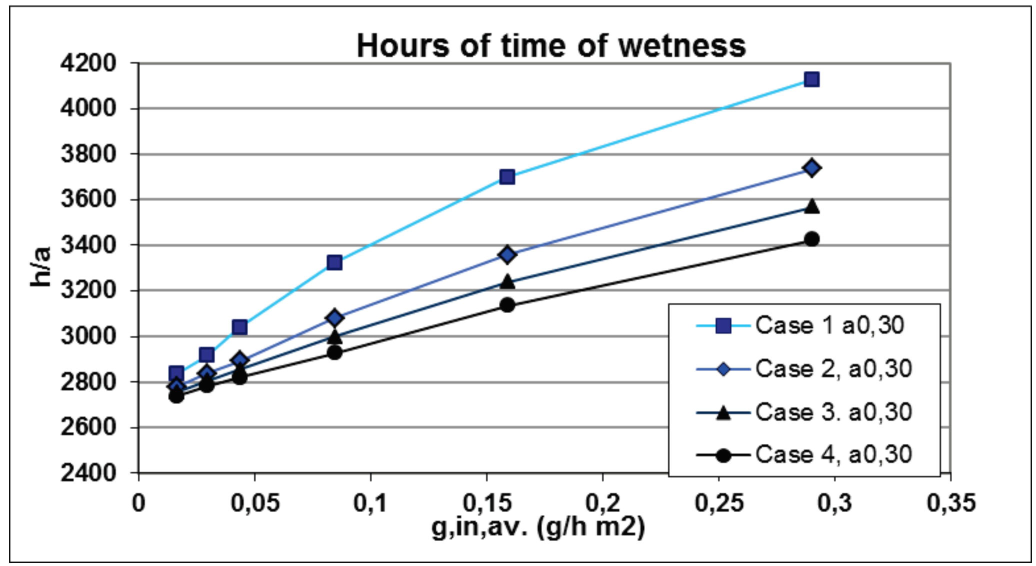
- No surface treatment
- Starting time $\alpha$ more interesting than mass loss



# Condensation and wet time index

- Wet time: >80% RH and > 0 $^{o}$C
- Wet time index is used for corrosion studies and material life time expectancy analysis



# Freeze / Thaw cycles

- For the climate load analysis of brick and mortar structures/ materials

# Summary

- Mold Index gives the firs risk prediction
- No mold (index < 1) in structure parts having contact to indoor air
- More flexible with exterior structures
- Decay needs much more time and higher moisture conditons than mold
- Decay mainly for exterior parts
- Wet time index and corrosion
- Freeze/thaw effects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