Moisture and biodeterioration risk of building materials and structures

Hannu Viitanen¹, Juha Vinha², Kati Salminen², Tuomo Ojanen¹, Ruut Peuhkuri¹, Leena Paajanen¹, Kimmo Lähdesmäki²

¹ VTT, Technical Research Centre of Finland, Espoo, Finland
² Department of Civil Engineering, Tampere University of Technology, Tampere, Finland.
Ageing / biodeteriodation / damages

• During the service life of buildings, natural ageing of materials due to different chemical, physical, and biological processes can take place.

• Grey wood is a normal phenomenon in outside conditions on untreated wood (caused partly by discolouring fungi).

• In damage cases, more severe changes of material are associated (mould growth, decay, insects, plants, animals).
Mould and decay in buildings

• Level and duration of moisture stress connected with temperature are the most critical factors for the durability of building materials and decay.

• Mould fungi, algae and lichens grow on the surface of many materials, e.g. textiles, leather, coatings, paper, wood, plastics, brickwork and concrete.
 Loads on a building during the service life

- **humidity**, **temperature**, **material**, **time period**, **organisms**

**Moisture stress** → **Ageing**

**MOISTURE DAMAGE**
- tolerances are overloaded

**MOULD**
- RH: > 75 - 95 %
- Temp: 0 - 55 C
- Time: d, w, m

**DECAY**
- RH: > 90 - 95 %
- Temp: 5 - 50 C
- Time: w, m, y

Detection the damages and simulation the causes of problems
Organisms causing problems in different building components

**Attics:** mould, blue-stain, insects

**Facades:** mould, blue stain, algae, lichens (decay: Gloeophyllum, Dacrymyces)

**Balconies, fences, terraces:** algae, lichens, mould, blue stain, decay: Gloeophyllum, Coniophora, Leucogyrophana etc, insects

**Wood in ground contact or water damages:** soft rot, white rot, bacteria, brown rot: Poria, Serpula etc, insects,
Problems in different part of building (1)

- **Wet rooms:**
  - Water penetration through inside surface or pipe leakage
  - High indoor humidity
  - Connected with other problems in building envelope
Problems in different part of building (2)

• **Floors and lower parts of walls:**
  Moisture transport (capillary or diffusion), evaporation from the ground and water condensation
  - high humidity and condensation
    in cold ventilated basement
  - wooden beams on uninsulated concrete slab in ground
  - pipe leakage and other water damages
  - lower part of wall in ground contact

**Typical organisms:**
Several types of mould and decay fungi
Bacteria
Insects
Termites
Animals
Problems in different part of building (2)
Facades, claddings and fences:

High weathering risk, building near open waterfront, driving rain, wood partly in ground contact, critical structure of details (water accumulation and sink), different type of defects

Typical organisms:
- Mould and blue- stain fungi
- Gloeophyllum trabeum,
- Antrodia serialis
- Insects, rodents
Wood in ground contact or water damage of building

- Typical organisms:
  - **Dry rot fungus**
  - Poria placenta
  - Coniophora puteana
  - Leucogyrophana
  - **Bacteria**
  - Different soft rot and white rot fungi
  - Mould fungi

- **Insects**
- **Termites**
- **Animals**
A building is an individual and whole unit

- service life and durability aspects of materials, building components and buildings: intended use condition / damage condition
- environment, exposure and use conditions, design, construct, maintenance and repair of a building with overall functionality in mind
- simple, clear operating instructions and service
- preventive maintenance and repair
- co-operation of different parties (experts of the building field, health and building authorities and biology experts)
- clear definition and concept of different problems and limit states: -> mould growth -> decay development -> damages -> accepted functions of different building components -> safety and security
- performance degree and limit states
- overall function / details: testing - function of the components -> worst case scenario / natural conditions
Service life, ISO 15686

SL of whole structure / details
- moisture accumulation in details -> critical also for the whole structure
- testing of details -> laboratory scale -> worst case scenario for "wrong details"
- reparation of details ?
- mould model is a tool for evaluate lower exposure conditions
- separate decay models

Building performance life cycle as a function of quality, performance degree (PD), failure, maintenance, refurbishment, repair and replacement (ISO 15686-7).
**Organisms involving damages and defects of building components** [Viitanen and Salonvaara 2001]

<table>
<thead>
<tr>
<th>Organism</th>
<th>Damage / problem type</th>
<th>Humidity or moisture range (RH or MC %)</th>
<th>Temperature range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>bacteria</td>
<td>biocorrosion of many different materials, smell, health problems</td>
<td>wet materials&lt;br&gt;RH &gt; 97 %</td>
<td>ca -5 to +60</td>
</tr>
<tr>
<td>mould fungi</td>
<td>surface growth on different materials, smell and health problems</td>
<td>Ambient RH &gt; 75 %, depends on duration, temperature and species</td>
<td>ca 0 to +50</td>
</tr>
<tr>
<td>blue-stain fungi</td>
<td>blue-stain of wood&lt;br&gt;permeability change of wood</td>
<td>Wood moisture content &gt; 25 - 120 %, RH &gt; 95 %</td>
<td>ca -5 to +45</td>
</tr>
<tr>
<td>decay fungi</td>
<td>different type of decay in wood (soft rot, brown rot or white rot), also many other materials can be deteriorated, strength loss of materials.</td>
<td>Ambient RH &gt; 95 %, MC &gt; 25 - 120 %, depends on duration, temperature, fungus and materials</td>
<td>ca 0 to +45</td>
</tr>
<tr>
<td>algae and lichen</td>
<td>surface growth of different materials on outside or weathered material.</td>
<td>wet materials&lt;br&gt;also nitrogen and low pH are needed</td>
<td>ca 0 to +45</td>
</tr>
<tr>
<td>insects</td>
<td>different type of damages in organic materials, surface failures or strength loss.</td>
<td>Ambient RH &gt; 65 %&lt;br&gt;depends on duration, temperature, species and environment</td>
<td>ca 5 to +50</td>
</tr>
</tbody>
</table>
Critical conditions for mould (weeks) and decay (months) on pine sapwood
MATHEMATICAL MODELING OF MOISTURE BEHAVIOUR AND MOULD GROWTH IN BUILDING ENVELOPES

Project team

• TTY: Kati Salminen, Juha Vinha (project leader), Kimmo Lähdesmäki, Tomi Strander
• VTT: Hannu Viitanen, Tuomo Ojanen, Ruut Peuhkuri, Leena Paajanen, Hanna Iitti, Liisa Seppänen
• Industrial partners
This study concentrates on materials and conditions which have not been tested or discussed in earlier studies.
MATERIAL EXPERIMENTS IN LABORATORY

<table>
<thead>
<tr>
<th>Constant/cyclical conditions</th>
<th>Test condition 1</th>
<th>Test condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>97% RH / 22°C</td>
<td>97% RH / 22°C</td>
</tr>
<tr>
<td>Cycle 4 – 8 weeks</td>
<td>97% RH / 22°C</td>
<td>97% RH / -5°C</td>
</tr>
<tr>
<td>Cycle 4 – 8 weeks</td>
<td>97% RH / 22°C</td>
<td>97% RH / -20°C</td>
</tr>
<tr>
<td>Cycle 4 – 8 weeks</td>
<td>97% RH / 22°C</td>
<td>50% RH / 22°C</td>
</tr>
<tr>
<td>Constant</td>
<td>97% RH / 5°C</td>
<td>97% RH / 5°C</td>
</tr>
<tr>
<td>Constant</td>
<td>97% RH / -5°C</td>
<td>97% RH / -5°C</td>
</tr>
<tr>
<td>Constant</td>
<td>90% RH / 22°C</td>
<td>90% RH / 22°C</td>
</tr>
<tr>
<td>Constant</td>
<td>90% RH / 5°C</td>
<td>90% RH / 5°C</td>
</tr>
<tr>
<td>Constant</td>
<td>97% RH / -20°C</td>
<td>97% RH / -20°C</td>
</tr>
</tbody>
</table>
Response of some building material to mould growth at RH 97 – 98 % / 22 °C

Surface subjected to mould suspension

Surface without added mould suspension
Response of some building material to mould growth at RH c.a. 90% / 22 °C

Surface subjected to mould suspension

Surface without added mould suspension
MATERIAL EXPERIMENTS IN FIELD CONDITIONS
STRUCTURE EXPERIMENTS IN LABORATORY

**Diagram:**
- Cooling units
- Heaters
- Structure to be tested
- Evaporator
- Sprinklers and radiation heater

**Table:**

<table>
<thead>
<tr>
<th>First test series</th>
<th>Second test series</th>
</tr>
</thead>
<tbody>
<tr>
<td>light concrete + glass wool</td>
<td>light concrete + polyurethane</td>
</tr>
<tr>
<td>light concrete + polyester wool</td>
<td>light concrete + expanded polystyrene</td>
</tr>
<tr>
<td>edge glued spruce board + glass wool</td>
<td>edge glued spruce board + polyurethane</td>
</tr>
<tr>
<td>edge glued spruce board + polyester wool</td>
<td>edge glued spruce board + expanded polystyrene</td>
</tr>
<tr>
<td>expanded clay aggregate concrete + glass wool</td>
<td>expanded clay aggregate concrete + polyurethane</td>
</tr>
<tr>
<td>expanded clay aggregate concrete + polyester wool</td>
<td>expanded clay aggregate concrete + expanded polystyrene</td>
</tr>
<tr>
<td>concrete + glass wool</td>
<td>concrete + polyurethane</td>
</tr>
<tr>
<td>concrete + polyester wool</td>
<td>concrete + expanded polystyrene</td>
</tr>
</tbody>
</table>

**Legend:**
- Detected interface
STRUCTURE EXPERIMENTS IN LABORATORY

Temperature

RH

Concrete - Glass wool

Edge glued spruce board - Glass wool
STRUCTURE EXPERIMENTS IN FIELD CONDITIONS

mould index = 0 after 6 months

\[ \text{RH}_{\text{interface}} = 60 - 70\% \text{ or } 80 - 90\% \ (gw, \ pw) \]
Modelling the mould
Criteria for mould growth

Generally, the models are
- based on measured data
  - regression analysis
  - isopleths
  - implementation of hygrothermal calculation principles on mould spores!
- isopleths and models are based on laboratory results of test using different mould fungi and different growth medium at regulated humidity and temperature conditions

[Clarke et al 1999] [Sedlbauer & Krus 2003]
Predicted mould growth on pine sapwood in different varied exposures at RH 97 % and 75 % (VTT model)

Decline of the mould index during dry periods
Measured climate for the material tests in field conditions

Measured climate data in Tampere experiments

- T, °C
- 48 per. Mov. Avg. (T)
- 48 per. Mov. Avg. (RH %)
- Weeks (June 22 - May 2)

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Comparison of VTT model (Viitanen) and Wufi-Bio (Sedbauer)

Comparison of Viitanen model and Wufi-Bio results

Solution using Tampere climate data and TCC2D simulations of T, RH and Mo fields
Calculation case: Construction

Construction from outside:

Jyväskylä weather

exterior sheathing
ventilated air cavity
12 mm wood chip board
150 mm mineral wool
12 mm gypsum board

inside diffusion resistances:
Sd = 0 m, 1 m and 3 m
Prediction of mould growth
Influence of diffusion resistance of vapor barrier
VTT model (pine sap wood) vs. Wufi-Bio (LIM I)
Conditions on the evaluated surface in element components in the laboratory: light concrete + glass wool
Development of mould on light weight concrete

![Graph showing development of mould on light weight concrete](image-url)

- K-Bet - laskettu
- Mitattu K-bet
- Mänty- ref, laskettu.
Decline of the mould development

Kevytbetoni - lasivilla -seinäkoe, mittaukset ja laskenta

- K-Bet - laskettu
- Mitattu K-bet
- K-Bet- laskettu - Ei taantumista

Homeindeksi

pvM

5.7.06 3.9.06 2.11.06 1.1.07 2.3.07 1.5.07 30.6.07 29.8.07 28.10.07

0,0 0,5 1,0 1,5 2,0 2,5 3,0 3,5 4,0
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• VTT
• Industrial partners

Thank you for your attention!