VTT Mold Model - From visual findings to mold index

Buildings XIII Workshop
How to Evaluate the Risk of Mold Using the Mold Growth Index
Tuomo Ojanen & Hannu Viitanen
Contents

- Motivation for the work
- Laboratory experiments and their analysis
- Setting the Mold Index
- Model for wood and other building materials
- Applications
Background and motivation for the mold model

- 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 surfaces
  - Increasing moisture may lead to structural damages

- natural ageing
  - grey wood
    - mould
      - indoor air
      - structures
        - VOCs
        - aesthetics
        - load exceeds tolerance
          - decay
          - damage
Measured or numerically solved relative humidity and temperature values – Risk or not?

- Need for deeper analysis of the conditions and time of exposure for different materials
Motivation - Moisture performance criteria

- One single RH level is not enough as a criteria
- Need to take into account temperature, RH and time
- Hannu Viitanen started experiments with wood - Most sensitive building material to biological growth
- Work started already in 1990’s
- Mold model for wooden material published in 1999

Mold Index

- Mold growth potential can be predicted by solving a numerical value, MOLD INDEX
- Values between [0, 6] depending on the growth coverage
Experiments under laboratory conditions

- Constant or cyclic conditions
Mold Index levels on wooden surface

Set Mold Index level \([0, 6]\) based on visual findings

Index 1 (start of growth, wood)

Index 3 - 4, wood,

Index 4, wood,

Index 5, wood,

Index 6, wood

Increasing growth level
Mold Index levels on concrete surface

Set Mold Index level [0, 6] based on visual findings

Index 2, concrete

Index 3, concrete

Index 5, concrete

Index 6, concrete

Increasing growth level
Interpretation of visual findings

- Typically several (5 – 9) parallel samples
- Maximum, mean, upper quarter or average value for the index?
- Average values used

Spruce board, RH 97%, +22 C

![Graph showing mold index over weeks for top surface, lower surface, and pine reference.](image-url)
## Mold index levels and definitions - Visual findings interpreted as mold index values

<table>
<thead>
<tr>
<th>Index</th>
<th>Description of the growth rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No growth</td>
</tr>
<tr>
<td>1</td>
<td>Small amounts of mould on surface (microscope), initial stages of local growth</td>
</tr>
<tr>
<td>2</td>
<td>Several local mould growth colonies on surface (microscope)</td>
</tr>
<tr>
<td>3</td>
<td>Visual findings of mould on surface, &lt; 10 % coverage, or, &lt; 50 % coverage of mould (microscope)</td>
</tr>
<tr>
<td>4</td>
<td>Visual findings of mould on surface, 10 - 50 % coverage, or, &gt;50 % coverage of mould (microscope)</td>
</tr>
<tr>
<td>5</td>
<td>Plenty of growth on surface, &gt; 50 % coverage (visual)</td>
</tr>
<tr>
<td>6</td>
<td>Heavy and tight growth, coverage about 100 %</td>
</tr>
</tbody>
</table>
Mold growth model for wood (spruce, pine)

- Forms the basis solver for all materials

\[
M = \exp(-0.68 \ln T - 13.9 \ln RH + 0.14W - 0.33SQ + 66.02)
\]

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

\[
k_1 = \begin{cases} 
1, & \text{when } M < 1 \\
\frac{2}{t_v / t_m - 1}, & \text{when } M > 1 
\end{cases}
\]

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

\[
\frac{dM}{dt} = \begin{cases} 
-0.032, & \text{when } t - t_1 \leq 6 \text{ h} \\
0, & \text{when } 6 \text{ h} \leq t - t_1 \leq 24 \text{ h} \\
-0.016, & \text{when } t - t_1 > 24 \text{ h}
\end{cases}
\]
Mold growth under dynamic conditions

- Pine sapwood under cyclic humidity conditions: RH 97 % and 75 %
- Dynamic conditions slow down the growth due to:
  - Delays in surface humidity conditions
  - Effect on mold growth
Different materials – Different growth intensity

RH 97 %, 23 °C

- particle board
- fibre board
- plywood
- gypsum
- concrete
- cement screed
- pine

Mould index

Time (week)
Mold growth intensity classes

![Graph showing mold growth intensity classes over time for different materials at RH 97% and 23°C. The graph plots mold index against time (in weeks) for particle board, fibre board, plywood, gypsum, concrete, cement screed, and pine.]
Maximum mold index levels under different conditions

Maximum levels of growth
Classification according material types
Mold sensitivity classes

- Set according to material mold test results
- Valid for tested materials – gives first approximation of mold growth sensitivity for materials/products

Peuhkuri, R; Viitanen, H; Ojanen, T. Modelling of mould growth in building envelopes
Proceedings of the IEA ECBCS Annex 41
Closing seminar, Copenhagen, June 19, 2008
Same mold growth pattern for all materials

- The VTT Mold Growth Model can be applied to other building materials using scaling factors
VTT mold model equations - Reference material pine

\[
\frac{dM}{dt} = \frac{1}{7 \cdot \exp(-0.681n T - 13.91n RH + 0.14W - 0.33SQ + 66.02)} k_1 k_2
\]

\[
k_1 = \begin{cases} 
\frac{t_{M=1,\text{pine}}}{t_{M=1}}, & \text{when } M < 1 \\
\frac{(t_{M=3,\text{pine}} - t_{M=1,\text{pine}})}{(t_{M=3} - t_{M=1})}, & \text{when } M \geq 1
\end{cases}
\]

\[
k_2 = \max[1 - \exp[2.3 \cdot (M + M_{\text{max}})], 0]
\]

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

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

More in model equation presentation …
Growth on soiled surfaces - 1

+20 C / 98 % RH conditions
Effect of organic dust on surface

- Mold growth sensitivity of soiled surface approaches that of pine
- Pine model can be used to present the first risk approximation for mold growth of old and soiled material surfaces
VTT Mold Model - 1

- Model developed at VTT by Hannu Viitanen et. al.
- Based on building biotechnical know how
- Basic model applied for different materials using coefficients
- All modelling for different materials carried out by VTT
- Material sensitivity classes set in one collaboration project with Tampere University of Technology
VTT Mold Model - 2

- Model can be only as good as the data behind it:
  - Variations inside same materials / different products
  - Interpretation of mold index findings
  - Use material classification when product has not studied separately
- Best for **risk analysis**, exact simulations of growth seldom needed
- Does the index level cause risks to indoor air or correlate to other moisture problems for structures
VTT Mold Model – Some references


TECHNOLOGY FOR BUSINESS