Hysteresis and Temperature Dependency of Moisture Sorption - New Measurements

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Hysteresis and temperature effect

- Moisture sorption of building materials exhibit hysteresis in the way the equilibrium curves develop between adsorption and desorption.
- Sorption curves are also somewhat temperature dependent.

These two facts are still most often neglected in models for combined heat and moisture transport in materials. There is need for further elaboration of the importance of these issues, and provision of background data.
Sorption curve for concrete as one unique curve

CONCRETE w/c=0.52  2300 kg/m³  20.0°C

Hansen, 1986
Kelsey, 1957
Sorption Space \((\varphi, T, u)\)  
(Norway Spruce)

Sorption characteristics can be represented as a body in the three-dimensional space, defined by axes for relative humidity, temperature, and moisture content.

The body is confined between a lower surface for adsorption, and an upper surface for desorption.
Hedlin, 1967
New measurements

• The paper contributes to the knowledge base by presenting new measurements of hysteresis and temperature dependency of the moisture sorption characteristics of three different porous building materials
• Scanning curves are measured for all three materials where periods with adsorption and desorption interrupt each other intermittently
• For one of the materials, aerated concrete, the sorption curves are determined at three different temperatures
Equipment

Desiccator with small jars

Sorption balance (DVS)
Salts used in desiccators and their equilibrium relative humidity (at 23°C)

<table>
<thead>
<tr>
<th>Salt</th>
<th>Equilibrium RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgCl</td>
<td>33 %</td>
</tr>
<tr>
<td>Mg(NO₃)₂</td>
<td>53 %</td>
</tr>
<tr>
<td>NH₄Cl</td>
<td>79 %</td>
</tr>
<tr>
<td>KNO₃</td>
<td>94 %</td>
</tr>
</tbody>
</table>
Exposure of samples subjected to hysteretic relative humidity exposure

<table>
<thead>
<tr>
<th>Adsorption tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry$_{105^\circ C}$ - 94%</td>
</tr>
<tr>
<td>Dry$_{105^\circ C}$ - 79%</td>
</tr>
<tr>
<td>Dry$_{105^\circ C}$ - 53%</td>
</tr>
<tr>
<td>Dry$_{105^\circ C}$ - 33%</td>
</tr>
</tbody>
</table>

Adsorption tests were followed by desorption scans
Desorption tests were followed by adsorption scans
Materials

Three hygroscopic materials were used for testing:

Cement paste  
- Water-cement ratio: 0.5  
- The cement paste is six years old and well carbonated since it has been stored in air

Aerated concrete  
- A light-weight product from H+H Celcon. Density: 380 kg/m³

Spruce
Cement Paste – Adsorption and desorption curves
Cement Paste –
Adsorption with subsequent desorption scans
Cement Paste – Desorption with subsequent adsorption scans
Aerated Concrete – Adsorption and desorption curves

Moisture Content, weight-%

Relative Humidity, %

Adsorption
Desorption
Aerated Concrete – Adsorption with subsequent desorption scans

![Diagram showing moisture content as a function of relative humidity with different desorption scans.](image-url)

- Desorption
- Scan 53-33-53
- Scan 79-33-79
- Scan 94-33
- Adsorption

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Aerated Concrete –
Desorption with subsequent adsorption scans

Moisture Content, weight-%

Relative Humidity, %

- Desorption
- Scan 33-94
- Scan 53-94-53
- Scan 79-94
- Scan 79-94
- Adsorption
Spruce – Adsorption and desorption curves

Moisture Content, weight-%

Relative Humidity, %
Spruce - Adsorption with subsequent desorption scans

![Graph showing moisture content vs relative humidity](image)

- Desorption
- Scan 53-33-53
- Scan 79-33-79
- Scan 94-33
- Adsorption
Spruce – Desorption with subsequent adsorption scans

![Graph showing moisture content vs. relative humidity. The graph includes lines for desorption and adsorption, with specific scans indicated.]
Aerated Concrete - Adsorption and desorption curves at different temperatures (DVS - sorption balance)
Aerated Concrete - Mean sorption curves at different temperatures
Conclusions

• New experimental data have been produced regarding hysteresis and temperature dependency for three different hygroscopic materials
• Further investigations of this kind may be worth pursuing
• The automatic sorption balance apparatus appears to be a useful instrument in such investigations