Basic building physics for museums

Poul Klenz Larsen, The National Museum of Denmark
Temperature control
Little thermal stability on daily cycle
Heat radiation warms up the interior during the day

Solid steel
1 cm thickness

30 °C
Temperature control

... and cool it during night

Little thermal capacity

10 °C
Humidity control

The structure is water thight

The surface is impermable to water vapour

No humidity buffer capacity
Humidity control

Water vapour comes with air infiltration

Air Exchange Rate \( AER \sim 0 \text{ h}^{-1} \)

30-100 %RH
Temperature control
Little temperature stability
Heat radiation is counterbalanced by mechanical cooling
Temperature control
Little thermal insulation
Heat loss is counterbalanced by heating

Double textile skin
Humidity control
Little humidity stability
The RH was controlled by humidification / dehumidification.
Nydambåd 14-07-2003 til 01-10-2003

Temp.  RH
Climate control

The ’building envelope’ was very leaky

Poor climate control – large energy consumption

Double textile skin
Temperature control
Solar heating through the glass roof
Heat absorption in walls and floor

Solid concrete

23 °C
60 %RH
Temperature control
Heat loss is large in winter

Solid concrete

0 °C
90% RH
Tegners Museum

- 619070 Temperature Tegners Museum
- 619070 Humidity Tegners Museum

Temperature (°C) vs. Humidity (%RH) vs. Time (2012)

Temperature graph shows a fluctuating trend with peaks and troughs throughout the year. Humidity graph exhibits a more consistent pattern with minor variations. Both metrics are presented from October 2011 to October 2012.
A shelter for fighter airplanes protecting against a nuclear strike.
The roof is 50 cm solid concrete covered with plastic paint.
In use as temporary store for collection of furniture
The store is densely packed with moisture sensitive wooden objects
Temperature control

Large thermal stability on daily cycle
The heat is absorbed during the day

Solid concrete
50 cm thickness

10 °C
Temperature control

... and is released to the outside during night

Large thermal capacity

10 °C
Temperature control

No thermal stability on annual cycle
The store heats up during summer
....and cools down during winter
Temperature and humidity buffering

Harmonic cycles

37%

1%
Periodical penetration depth (37%) for a 24 hours harmonic swing

<table>
<thead>
<tr>
<th>Material</th>
<th>Depth (m)</th>
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<tbody>
<tr>
<td>Wood</td>
<td>0.07</td>
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<tr>
<td>Light weight concrete</td>
<td>0.09</td>
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<tr>
<td>Brick</td>
<td>0.11</td>
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<tr>
<td>Concrete</td>
<td>0.15</td>
</tr>
<tr>
<td>Mineral wool</td>
<td>0.16</td>
</tr>
<tr>
<td>Granite</td>
<td>0.21</td>
</tr>
<tr>
<td>Steel</td>
<td>0.65</td>
</tr>
</tbody>
</table>

1%
Temperature control
Walls and roof must be 4 m thick to even out annual variation

Solid concrete
10 - 12 °C
90% RH
Temperature control
Walls and roof must be 4 m thick to even out annual variation.