Designing energy efficient buildings with WUFI & WUFI Plus Software

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Moisture Problems

Moisture Designs are needed that minimize the risk for damage
Introduction – Moisture Safety Factor

Dynamic moisture balance

Safe Storage Capacity

Indoor air loads.
- air convection
- vapor diffusion

Wetting

Rain penetration
Ext. condensation

Built-in

Drying

Drainage
Evaporation-Diffusion
Dynamic moisture balance

Safe Storage Capacity

Wetting

Drying

To avoid failure or damage --- Maximize the drying potential!
Moisture is Dynamic
Tools needed to:

- Climate Data
- Construction Data
- Material Data

Hygro-thermal Envelope Simulation (WUFI)

Service Performance (biological, chemical, Mechanical resistance)
Limitations of WUFI 1-D

- It is 1-D
- User Input for interior boundary conditions
  - Need to specify (T, & RH for every hour)
  - No impact on other components
    (# of windows, facing orientation, etc)
- No air flow

Used Primarily for envelope analysis
Unique Capabilities for Whole Building Analysis
Room

Heat balance

\[ \rho \cdot c \cdot V \cdot \frac{dT_i}{dt} = \dot{Q}_{\text{component}} + \dot{Q}_{\text{window}} + \dot{Q}_{\text{IWQ}} + \dot{Q}_{\text{vent}} + \dot{Q}_{\text{RLT}} \]

Moisture balance

\[ V \cdot \frac{dc_i}{dt} = \dot{W}_{\text{component}} + \dot{W}_{\text{vent}} + \dot{W}_{\text{IFQ}} + \dot{W}_{\text{RLT}} \]
Heat loads - occupants
Moisture loads - daily routine

Water Vapour, litres

- 4 Occupants / Day
- Clothes drying inside / Day
- Floor Washing 12 m²
- Cooking on Gas Stove
- Gas Refrigerator / Day
- Cooking (3 Meals)
- Dishwashing (3 Meals)
- 5 Average Size Plants / Day
- per Shower
- per Bath

Moisture loads - daily routine
## CO2 loads - occupants

<table>
<thead>
<tr>
<th>Activity</th>
<th>W/m²</th>
<th>Met</th>
<th>CO₂/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclining</td>
<td>46</td>
<td>0.8</td>
<td>13.6</td>
</tr>
<tr>
<td>Seated relaxed</td>
<td>58</td>
<td>1.0</td>
<td>17</td>
</tr>
<tr>
<td>Standing relaxed</td>
<td>70</td>
<td>1.2</td>
<td>20.4</td>
</tr>
<tr>
<td>Seated activity (office, dwelling, school, laboratory)</td>
<td>70</td>
<td>1.2</td>
<td>20.4</td>
</tr>
<tr>
<td>Standing, light activity (shopping, laboratory, light industry)</td>
<td>93</td>
<td>1.6</td>
<td>0</td>
</tr>
<tr>
<td>Teacher</td>
<td>96</td>
<td>1.6</td>
<td>27.2</td>
</tr>
<tr>
<td>Standing, medium activity (shop assistant, domestic work)</td>
<td>115</td>
<td>2.0</td>
<td>27.2</td>
</tr>
<tr>
<td>Building industry - Brick laying (Block of 16.3 kg)</td>
<td>125</td>
<td>2.2</td>
<td>34</td>
</tr>
<tr>
<td>Washing dishes standing</td>
<td>145</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Domestic work - raking leaves on the lawn</td>
<td>170</td>
<td>2.9</td>
<td>37.4</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>319</td>
<td>5.5</td>
<td>42.5</td>
</tr>
<tr>
<td>Aerobic Dancing</td>
<td>348</td>
<td>6.0</td>
<td>49.3</td>
</tr>
<tr>
<td>Basketball</td>
<td>348</td>
<td>6.0</td>
<td>49.3</td>
</tr>
<tr>
<td>Swimming</td>
<td>348</td>
<td>6.0</td>
<td>49.3</td>
</tr>
<tr>
<td>Sports - Ice skating, 18 km/h</td>
<td>360</td>
<td>6.2</td>
<td>93.5</td>
</tr>
<tr>
<td>Agriculture - digging with a spade (24 lifts/min,)</td>
<td>380</td>
<td>6.5</td>
<td>102</td>
</tr>
<tr>
<td>Sports - Running in 15 km/h</td>
<td>550</td>
<td>9.5</td>
<td>0</td>
</tr>
</tbody>
</table>
# Results 6. run

## Case 1/Zone 1: Main results

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating period [d]</td>
<td>190,3</td>
<td>245</td>
</tr>
<tr>
<td>Cooling period [d]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating load [kWh]</td>
<td>6030,3</td>
<td>159,94</td>
</tr>
<tr>
<td>Cooling load [kWh]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Humidification load [kg]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dehumidification load [kg]</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

## Min/Max/Mean Values

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner temperature [°C]</td>
<td>20</td>
<td>33,9</td>
<td>21,8</td>
</tr>
<tr>
<td>Inner relative humidity [%]</td>
<td>67,2</td>
<td>100</td>
<td>87,4</td>
</tr>
<tr>
<td>Heating power [kW]</td>
<td>0</td>
<td>4,8</td>
<td>0,9</td>
</tr>
<tr>
<td>Cooling power [kW]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Humidification [kg/h]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dehumidification [kg/h]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specification</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner temperature [°C]</td>
<td>20</td>
<td>34,1</td>
<td>21,2</td>
</tr>
<tr>
<td>Inner relative humidity [%]</td>
<td>14,8</td>
<td>30,3</td>
<td>48,4</td>
</tr>
<tr>
<td>Heating power [kW]</td>
<td>0</td>
<td>7,4</td>
<td>1,8</td>
</tr>
<tr>
<td>Cooling power [kW]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Humidification [kg/h]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dehumidification [kg/h]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Comfort Performance
This standard amount of insulation required to keep a resting person warm in a windless room at 70 °F (21.1 °C) is equal to one clo.
Simplified approach

Knoxville, TN

Annual

V=375 m³

Indoor Humidity [%]

Air Change Rate [h⁻¹]

- no M.P.
- 200 g/h
- 500 g/h
- 1000 g/h
Simplified approach using 1-D Analysis

Knoxville, TN

Annual

Monthly

V=375 m³

V=375 m³

n=0.5 ACH
M.P.=500 g/h

Indoor Humidity [%]

Air Change Rate [h⁻¹]

Month
What choices to we have with 1-D?
Boundary Conditions in WUFI

**Temperature / Relative Humidity**

**Air-conditioning system**
- **AC Type**: AC with Dehumidification
- **Floating indoor temperature shift [°C]**: 2.8
- **Set point for heating [°C]**: 21.1
- **Set point for cooling [°C]**: 23.9
- **R.H. control setpoint [%]**: 50

**Relative Humidity**
- **Moisture Generation Rate**
  - **Number of bedrooms**: 5
  - **Jetted tub without exhaust fan**: False
  - **User Defined Moisture Generation Rate**: False
  - **Moisture Generation Rate [kg/s]**: 1.80E-04
- **Air Exchange Rate**
  - **Standard construction**: True
  - **Air Exchange Rate [1/h]**: 0.2
  - **Building volume [m³]**: 375

**Last Calculation**: 29.11.2007
Boundary Conditions in WUFI
Boundary Conditions in WUFI

Knoxville, TN

Moisture Content in the OSB Board [M-%]

Time since 1st October [years]

- Sine
- EN 13788
- EN 15026
- SPC 160 - heating 2 rooms
- SPC 160 - heating 5 rooms
- SPC 160 - heating AC
- SPC 160 - heating AC with Dehum.
Boundary Conditions in WUFI

Charleston, SC

Moisture Content in the OSB Board [M.-%]

Time since 1st October [years]

- Sine
- EN 13788
- EN 15026
- SPC 160 - heating 2 rooms
- SPC 160 - heating 5 rooms
- SPC 160 - heating AC
- SPC 160 - heating AC with Dehum.
Hygro-thermal Envelope Simulation (WUFI)

Whole Building Simulation

Energy Consumption, Comfort

Service Performance (biological, chemical, Mechanical resistance)

Climate Data

Construction Data

Material Data
Magic Circles

- Ventilation
- Moisture Sources
- Mold Growth
- Energy
- Building Science
- Comfort
Conclusions

• Component building envelope modeling is important but there is risks with assumptions of indoor loads.

• Energy efficiency strategies need to be evaluated (Moisture Control). Adding higher R-values require additional attention to moisture control designs.

• Integrated whole building (HAM) software are very valuable to the designer.

• Comfort is more desirable and now more quantifiable.