Is ventilative cooling effective in light weight wooden constructions?

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Koen Claes (Thomas More)
Kim Goethals (UGent)
Lieven De Boever (TCHN)
• Sustainable innovation wood based applications
  – Air tightness, water & wind tightness
  – Hygrothermal performance
  – Construction and fire safety
  – Acoustics
  – Indoor air quality
  – Summer Comfort
  – Case studies
  – Sustainable management

• Financial support of IWT, BBRI, TCHN
• Summer Comfort
  – Development design guidelines in light weight wooden construction (KAHO, Thomas More)
    • Sensitivity analysis
    • Guidelines residential <> office buildings
  – Optimalisation existing EPBD legislation (UGent)
    • Development of overheating indicator for light weight wooden construction
    • Optimalisation overheating indicator
Summary

• Context
• Design challenges
• Reference buildings
• Method
• Results
• Conclusions
Design challenges

- Ventilative cooling in light weight constructions?
- Impact of weather data on prediction cooling need/overheating risk
Summary

- Context
- Design challenges
- Reference buildings
  - Quality levels
  - Residential <-> office buildings
  - Characteristics: building – HVAC - user
- Method
- Results
- Conclusions
Reference Buildings

- 2 Quality levels: building envelop
  - Insulation level
  - Air tightness
- Flemish EPBD (2014) <> PH standard

<table>
<thead>
<tr>
<th></th>
<th>EPBD 2014</th>
<th>PH standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>U [W/m²K]</td>
<td>U [W/m²K]</td>
</tr>
<tr>
<td>Façade/Roof/Floor</td>
<td>0,24</td>
<td>0,15</td>
</tr>
<tr>
<td>Window – glazing</td>
<td>1,1</td>
<td>0,8</td>
</tr>
<tr>
<td>Window – frame</td>
<td>1,8</td>
<td>0,8</td>
</tr>
<tr>
<td>External door</td>
<td>2,0</td>
<td>0,8</td>
</tr>
<tr>
<td>n₅₀ (h⁻¹)</td>
<td>3</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Reference Buildings

- Residential: detached house
  - $A_{\text{floor, tot}} = 252 \text{ m}^2$
  - Zone 1
Reference Buildings

- Office building
  - Zone 1: $A_{\text{floor}} = 200 \text{ m}^2$
## Reference Buildings

### Characteristics: walls

<table>
<thead>
<tr>
<th>Material</th>
<th>(c) [J/kg.K]</th>
<th>(\rho) [kg/m³]</th>
<th>(\lambda) [W/m.K]</th>
<th>(d) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>façade</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>structure - wood fraction (15%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.300</td>
</tr>
<tr>
<td>structure - MW (85%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.300</td>
</tr>
<tr>
<td>OSB</td>
<td>1700</td>
<td>650</td>
<td>0.130</td>
<td>0.015</td>
</tr>
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<td>cavity - wood fraction (15%)</td>
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<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.050</td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>internal wall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gypsum board</td>
<td>1000</td>
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<td>1000</td>
<td>900</td>
<td>0.260</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>internal floor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>floor covering</td>
<td>1400</td>
<td>1200</td>
<td>0.190</td>
<td>0.010</td>
</tr>
<tr>
<td>OSB</td>
<td>1700</td>
<td>650</td>
<td>0.130</td>
<td>0.015</td>
</tr>
<tr>
<td>structure - wood fraction (11%)</td>
<td>1600</td>
<td>500</td>
<td>0.130</td>
<td>0.200</td>
</tr>
<tr>
<td>structure - MW (89%)</td>
<td>1030</td>
<td>50</td>
<td>0.040</td>
<td>0.200</td>
</tr>
<tr>
<td>gypsum board</td>
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<td>900</td>
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**Reference Buildings**

- Characteristics: walls

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<th>$\lambda$ [W/m.K]</th>
<th>$d$ [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tiles</td>
<td>1000</td>
<td>1700</td>
<td>0.810</td>
<td>0.010</td>
</tr>
<tr>
<td>light concrete</td>
<td>1000</td>
<td>1050</td>
<td>0.320</td>
<td>0.070</td>
</tr>
<tr>
<td>insulation</td>
<td>1400</td>
<td>30</td>
<td>0.035</td>
<td>0.170</td>
</tr>
<tr>
<td>light concrete</td>
<td>1000</td>
<td>1050</td>
<td>0.320</td>
<td>0.050</td>
</tr>
<tr>
<td>reinforced heavy concrete</td>
<td>1000</td>
<td>2400</td>
<td>2.200</td>
<td>0.150</td>
</tr>
</tbody>
</table>
Reference Buildings

- Characteristics: residential building
  - Solar shading
    - $g_{\text{window}} = 0.50$
    - Fixed overhang ($d = 1\text{m}$)
  - Hygienic ventilation rates
    - Zone 1: $n = 1 \text{ h}^{-1}$
  - Extra natural ventilation
    - Daytime ($T_i > 24^\circ\text{C}, 7\text{h}-22\text{h}$)
    - Nighttime ($T_i > T_e+1^\circ\text{C}, T_i > 18^\circ\text{C}, 22\text{h}-7\text{u}$)
    - $n = 0 <> 3 \text{ h}^{-1}$
  - Thermal mass
    - Light weight wooden construction
    - Heavy weight brick internal walls
Reference Buildings

- Characteristics: residential
  - Internal heat gains (ISO 13791)
Reference Buildings

- Characteristics: Office building
  - Solar shading
    - $g_{\text{window}} = 0.55$
    - Fixed overhang ($d = 1\,\text{m}$)
  - Hygienic ventilation rates & occupancy
    - IDA 3 (29 $\text{m}^3/\text{h}$)
    - 15 $\text{m}^2$/pers
    - zone 1: $n = 0.67 \, \text{h}^{-1}$
  - Night ventilation
    - $n = 0 <> 3 <> 6 \, \text{h}^{-1}$
**Reference Buildings**

- Characteristics: Office building
  - Thermal mass

<table>
<thead>
<tr>
<th>Classification (EN 13790)</th>
<th>Heat capacity $C_m$ (J/K)</th>
<th>construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very light</td>
<td>$1.13 \times 10^7$</td>
<td>All light weight wooden walls</td>
</tr>
<tr>
<td>Light</td>
<td>$2.19 \times 10^7$</td>
<td>Functional core heavy concrete</td>
</tr>
<tr>
<td>Very heavy</td>
<td>$7.91 \times 10^7$</td>
<td>Functional core heavy concrete Internal floor + ceiling concrete slab</td>
</tr>
</tbody>
</table>
Reference Buildings

- Characteristics: Office building
  - Internal heat gains

![Graph showing internal heat gains in an office building](chart.png)
Summary

• Context
• Design challenge
• Reference buildings
• Method
  – Dynamic simulations
  – Evaluation overheating
• Results
• Conclusions
Method

• Multizone dynamic simulations
  – Design Builder (E+)
  – Time step = 1h
  – Cooling: $T_i > 26^\circ C$

• Evaluation overheating (EN 15251)
  – Comfort limit: $PMV = 0.5$ – $PPD = 10\%$
  – Weight factor
    \[ w_f = \frac{PPD_{actualPMV}}{PPD_{PMVlimit}} \]
  – Max weighted temperature exceedings
    5% on yearly basis = 438h residential
Summary

• Context
• Design challenges
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• Method
• Results
  – Impact ventilative cooling on cooling need & peak cooling load in office buildings
  – Impact ventilative cooling on overheating risk in residential buildings
  – Effect ventilative cooling in warm weather data
• Conclusions
Results

- Impact ventilative cooling on cooling need in office buildings
Results

- Impact ventilative cooling on peak cooling load in office buildings

![Graph showing peak cooling load with different ventilation rates]

- Peak Cooling [W/m²]
- very light
- light
- very heavy

- 0 vol/h
- 3 vol/h
- 6 vol/h
Results

- Impact ventilative cooling on peak cooling in office buildings
Results

- Impact ventilative cooling on overheating in residential buildings
Results

• Impact weather data on performances
  – Temperature
  – Solar radiation

• Meteonorm 7
  – Synthetical based on measurements
    • temperature (2000-2009)
    • Solar radiation (1986-2005)
  – Average <> Warm weather data (1 per 10 year)
# Results

- weather data: temperature

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Uccle (B)</th>
<th>Warm Uccle (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KMI 04-08</td>
<td>Meteonorm 7</td>
</tr>
<tr>
<td>1</td>
<td>4.83</td>
<td>4.00</td>
</tr>
<tr>
<td>2</td>
<td>4.58</td>
<td>4.90</td>
</tr>
<tr>
<td>3</td>
<td>6.57</td>
<td>7.10</td>
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<tr>
<td>4</td>
<td>10.86</td>
<td>10.70</td>
</tr>
<tr>
<td>5</td>
<td>14.20</td>
<td>14.40</td>
</tr>
<tr>
<td>6</td>
<td>17.03</td>
<td>17.20</td>
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<tr>
<td>7</td>
<td>18.76</td>
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<td>8</td>
<td>17.33</td>
<td>18.50</td>
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<tr>
<td>9</td>
<td>15.80</td>
<td>15.50</td>
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<tr>
<td>10</td>
<td>12.23</td>
<td>11.80</td>
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<tr>
<td>11</td>
<td>7.14</td>
<td>7.80</td>
</tr>
<tr>
<td>12</td>
<td>3.93</td>
<td>4.10</td>
</tr>
<tr>
<td>Annual average</td>
<td>11.11</td>
<td>11.22</td>
</tr>
</tbody>
</table>
Results

- Warm weather data: cooling need in office
Summary

- Context
- Design challenge
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Conclusions

• Is ventilative cooling effective in light weight wooden constructions
  – Office buildings: night ventilation
    • Cooling need: very effective
    • Peak cooling load: less effective - larger impact thermal mass
  – Residential buildings: day & night ventilation
    • Overheating: day ventilation effective

• warm weather data: impact ventilative cooling
  – Office buildings: night ventilation effective
  – Residential buildings:
    • Only day ventilation not effective
    • Need automatically controlled shading device -> good thermal comfort