Optimisation of energy efficiency measures in historic buildings

Prof. Andra Blumberga

Ritvars Freimanis, Indra Muižniece, Krišs Spalviņš, Dagnija Blumberga

4th International Conference on Smart Energy Systems and 4th Generation District Heating
13-14 November 2018, Aalborg
RiBuild: Robust internal insulation for historic buildings

www.ribuild.eu
Interdisciplinary research

- Innovative organic insulation material for historic buildings
- Smart Energy Systems, incl. 4th generation DH
- Bioeconomy strategy
- Changes in urban environment
- Energy efficiency in buildings goals
- Climate goals

Riga Technical University
Challenges

- Energy efficiency and heritage value are opposite goals
- Internal insulation is one of the most complicated EE measures
Porous materials
Moisture and porous materials

- Moisture transport
- Moisture accumulation
- Moisture sources:
  - Groundwater
  - Wind drive rain
  - Water losses from pipes
  - etc.
Moisture damages on external walls
Moisture damages on external walls
Internal insulation and condensation
Which insulation?
Insulation materials for internal insulation

Vapour tight systems

Capillary active insulation

http://www.knaufinsulation.lv/produkti/ecose-mineralvate-gmw

http://www.ecologicalbuildingsystems.com/Ireland/Products/Product-Detail/Calstherm-Board
Fossil based vs organic based materials

- Internal insulation can be carried out either with fossil or organic based insulation materials.

- **EU Bioeconomy Strategy** has set course for a resource-efficient and sustainable economy with the goal to reach more innovative and low-emissions economy by using renewable biological resources from land and sea to produce food, materials and energy.

- Application of **bioeconomy principles** to renovation of buildings is very actual.

- Although the life cycle of organic insulation materials is based on bioeconomy principles, currently they are avoided for internal insulation due to high moisture level which causes mould growth risks.
Previous research
Laboratory tests of massive walls

- Relative humidity:
  - Mineral wool with vapor barrier: 85.5%
  - EPS: 82%
  - Wood fiber without vapor barrier: 82%
  - Aerogel with vapor barrier: 81%
  - Wood fiber with vapor barrier: 76%
  - Aerogel with vapor barrier: 76%

- Temperature between brick wall and insulation materials: +10°C.

Indoor:
- Temperature +20°C
- RH 55%

Outdoor:
- Temperature 0°C
- RH 85%

- 22 days
- 2 test rounds
Woodfiber insulation

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Relative humidity: test1, %</th>
<th>Relative humidity: test2, %</th>
<th>Temperature: test1, °C</th>
<th>Temperature: test2, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1065</td>
<td>2129</td>
<td>3193</td>
<td>4257</td>
</tr>
<tr>
<td>2</td>
<td>1383</td>
<td>2129</td>
<td>3193</td>
<td>4257</td>
</tr>
<tr>
<td>3</td>
<td>15961</td>
<td>3193</td>
<td>4257</td>
<td>5321</td>
</tr>
<tr>
<td>4</td>
<td>17025</td>
<td>4257</td>
<td>5321</td>
<td>6385</td>
</tr>
<tr>
<td>5</td>
<td>18089</td>
<td>5321</td>
<td>6385</td>
<td>7449</td>
</tr>
<tr>
<td>6</td>
<td>19153</td>
<td>6385</td>
<td>7449</td>
<td>8513</td>
</tr>
<tr>
<td>7</td>
<td>20217</td>
<td>7449</td>
<td>8513</td>
<td>9577</td>
</tr>
<tr>
<td>8</td>
<td>21281</td>
<td>8513</td>
<td>9577</td>
<td>10641</td>
</tr>
<tr>
<td>9</td>
<td>22345</td>
<td>9577</td>
<td>10641</td>
<td>11705</td>
</tr>
<tr>
<td>10</td>
<td>23409</td>
<td>10641</td>
<td>11705</td>
<td>12769</td>
</tr>
<tr>
<td>11</td>
<td>24473</td>
<td>11705</td>
<td>12769</td>
<td>13833</td>
</tr>
<tr>
<td>12</td>
<td>25537</td>
<td>12769</td>
<td>13833</td>
<td>14897</td>
</tr>
<tr>
<td>13</td>
<td>26601</td>
<td>13833</td>
<td>14897</td>
<td>15961</td>
</tr>
<tr>
<td>14</td>
<td>27665</td>
<td>14897</td>
<td>15961</td>
<td>17025</td>
</tr>
<tr>
<td>15</td>
<td>28729</td>
<td>15961</td>
<td>17025</td>
<td>18089</td>
</tr>
</tbody>
</table>

75% < RH_{crit} < 80%
The goal of the study

- to find optimal solution for application of innovative organic insulation material made from pine needles for internal insulation of historic massive walls.
Interdisciplinary research

- Building physics
- Biology
- Material science
- Bioeconomy
Original wall
Computer simulation with Delphin
Raw material for insulation material

FOREST RESIDUALS → EXTRATION OF PINE GREENINGS → FRESH GREENINGS OF PINE + BINDER
Pine needle insulation material

- Density 58 kg/m³;
- Thermal conductivity 0.051 W/m/K
Hygrothermal properties of materials
Laboratory set up

- Indoor:
  - Temperature +20°C
  - RH 55%
- Outdoor:
  - Temperature 0°C
  - RH 85%
- 22 days
- Temperature, RH, heat flow metering
Mould growth test of insulation material

- Three moisture levels
- Inserted 5 mould types
- +20°C and darkness
- 20 days
Results
Tests of pine needle insulation in mould growth climate chamber

With lime  
Without lime
Without lime

https://powervacamerica.com/project/life-cycle-of-mold/
With lime

2 ml water and mould mixture

3 ml and 5 ml water and mould mixture
Temperature and RH between stone wall and insulation layer

Temperature, °C

Relative humidity, %

Riga Technical University

21.10.2018 00:00
23.10.2018 00:00
25.10.2018 00:00
27.10.2018 00:00
29.10.2018 00:00
31.10.2018 00:00
02.11.2018 00:00
04.11.2018 00:00

21.10.2018 00:00
23.10.2018 00:00
25.10.2018 00:00
27.10.2018 00:00
29.10.2018 00:00
31.10.2018 00:00
02.11.2018 00:00
04.11.2018 00:00

Without lime
With lime

Without lime
With lime
Conclusions

- Organic insulation material produced from forest residuals has high added value
- Lower temperatures leads to higher relative humidity level
- Heat savings have to be sacrificed to reduce failure modes (mould growth) if no lime additive is added
- Relative humidity between insulation and wall reaches critical value for mould growth
- Lime additives does not have impact on thermal conductivity but has impact on mould growth