Wood-based Thermal Insulation Materials - WOTIM

10th Johan Gullichsen Colloquium
19th November 2015
Petri Jetsu and Tiina Pöhler VTT
Outline

- WOTIM project
- Insulation markets
- Basics of foam forming
- Properties of foam formed cellulose based insulation materials
- Summary
WOTIM-project

Targets:
- Develop a high performance wood-based cellulosic thermal insulation panel material manufactured by foam forming to replace the synthetic insulation materials
- Develop a new bio-based in-situ spray-on thermal insulation foam based on cellulose to replace traditional spray-on synthetic insulation foams

Programme: WoodWisdom-Net
Budget: 1,46 milj. eur

More info http://wotim.eu/
WOTIM-project – Partners

Partners:
- **VTT** (RTD-Finland): Coordinator, development of thermal insulation panel and spray-on foam
- **Innventia** (RTD-Sweden): Fibre processing, characterization
- **FCBA** (RTD-France): Economic, ecological and health evaluations
- **Holmen** (Large-Sweden): Fibre supplier, fibre processing
- **Soprema** (Large-France): Insulation material manufacturer, performance evaluations

Co-funding companies:
- **Stora Enso** (Large-Finland): Fibre supplier, fibre processing
- **Ekovilla** (SME-Finland): Insulation material manufacturer
- **Neovo Solutions** (SME-Finland): Insulation material manufacturer
- **Interenergy** (SME-Finland): Fire retardant chemicals supplier
European Market for Insulation 2012

- The total market was approximately 5.6 million tonnes
- Estimated value was €9,600 million
- Annual growth rate 2.2%

The EU Directive of energy efficiency is a market driver!

- Glass wool 39%
- EPS 26%
- Stonewool 18%
- PU/PIR 10%
- XPS 6%
- Others 1%

EPS: Expanded polystyrene
PU/PIR: Polyurethane
XPS: Extruded polystyrene

Source: IAL Consultants, The European market for thermal insulation products
Definition of Thermal Conductivity

Thermal conductivity is the result of several components

\[ \lambda_T = \lambda_M + \lambda_G + \lambda_C + \lambda_R \]

- \( \lambda_M \): Thermal conductivity in the matrix
- \( \lambda_G \): Thermal conductivity through cell gas
- \( \lambda_C \): Convection in the cell gas
- \( \lambda_R \): Radiation
<table>
<thead>
<tr>
<th>Insulation product</th>
<th>Composition</th>
<th>λ (W/m K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral wool</td>
<td>Inorganic oxides</td>
<td>0.034–0.045</td>
</tr>
<tr>
<td>Glass wool</td>
<td>Silicon dioxide</td>
<td>0.031–0.043</td>
</tr>
<tr>
<td>Foam glass</td>
<td>Silicon dioxide</td>
<td>0.038–0.050</td>
</tr>
<tr>
<td>Expanded polystyrene (EPS)</td>
<td>Oil-based polymer foam</td>
<td>0.029–0.055</td>
</tr>
<tr>
<td>Extruded polystyrene (XPS)</td>
<td>Oil-based polymer foam</td>
<td>0.029–0.048</td>
</tr>
<tr>
<td>Phenolic resin foam</td>
<td>Oil-based polymer foam</td>
<td>0.021–0.025</td>
</tr>
<tr>
<td>Polyurethane foam</td>
<td>Oil-based polymer foam</td>
<td>0.020–0.029</td>
</tr>
<tr>
<td>Silica aerogels</td>
<td>SiO2 based aerogel</td>
<td>0.012–0.020</td>
</tr>
<tr>
<td>Organic aerogels</td>
<td>Aerogels derived from organic compounds, e.g. cellulose</td>
<td>0.012–0.020</td>
</tr>
<tr>
<td>Vacuum insulation panels (VIP)</td>
<td>Silica core sealed and evacuated in laminate foil</td>
<td>0.003–0.011</td>
</tr>
<tr>
<td>Vacuum glazing (VG)</td>
<td>Double glazing unit with evacuated space and pillars</td>
<td>0.003–0.008</td>
</tr>
</tbody>
</table>

Other Important Properties for Insulation Materials

- Fire resistance
- Water absorption
- Mould growth resistance
- Resistance against pests
- Compression strength / reversibility
- Bending strength

The importance of these and performance level needed depends heavily on application and structural solution!
Basics of Foam Forming

- Fibres and other raw materials are mixed with aqueous foam instead of water.
- Foam consists of water, foaming agent and air.
- Typical air content 50 – 70 %.
- Material is located in “bubble pockets”.
- Fibres are ”frozen” in their dispersed state leading to uniform material distribution.
Important Foam Characteristics

- ... which effect on the product properties and controlling of processes

- Foam density
  - air content

- Foam stability
  - Half life time (liquid volume reaches half of its initial height)

- Bubble size
Main Process Phases and Features

- Generation of foam and mixing of raw materials in the foam: In tank or on-line in tube
- Web forming: Foam removal with vacuums
- Wet pressing: Not used if aiming to highly porous structures
- Drying: With contact or non-contact techniques
- Process can be batch or continuous process
Potential of Foam Forming

- Possible to produce highly porous structures
- Possibility to get very uniform structures even with several centimetres long fibres
- Foam allows utilization of raw materials from long fibers to nanoscale particles as well as particles lighter than water
- Possibility to produce layered products with excellent layer purity
- Technology can be resource efficient and cost competitive compared to many other manufacturing methods
Properties of Foam Formed Cellulose Based Insulation Materials
Preparation of Foam Formed Materials

Phases:
- Fibre foam generation: Mixing of pulp suspension and foaming agent
- Sheet forming: Fibre foam is poured into a mould and drained by gravity
- Drying in the oven
- Rewetting to dsc. 50% and pressing to targeted thicknesses
- Drying in the oven

Foaming  Sheet forming  Pressing
## Samples and Testing Methods

<table>
<thead>
<tr>
<th>Pulp</th>
<th>Abb.</th>
<th>Fibre length mm</th>
<th>Freeness ml</th>
<th>Thickness mm</th>
<th>Density kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrefined softwood chemical pulp</td>
<td>SW</td>
<td>2.0</td>
<td>700</td>
<td>10…38</td>
<td>27…78</td>
</tr>
<tr>
<td>Unrefined hardwood chemical pulp</td>
<td>HW</td>
<td>0.8</td>
<td>650</td>
<td>17…39</td>
<td>23…75</td>
</tr>
<tr>
<td>Thermomechanical pulp</td>
<td>TMP</td>
<td>1.4</td>
<td>540</td>
<td>10…39</td>
<td>25…88</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Glass wool</th>
<th>Thickness mm</th>
<th>Density kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall insulation</td>
<td>100</td>
<td>29</td>
</tr>
<tr>
<td>Ceiling insulation</td>
<td>60</td>
<td>18</td>
</tr>
</tbody>
</table>

- Thermal conductivity: EN12667
- Compression strength: EN826
- Bending strength: ISOLE classification
- Water retention capacity: ISO17190-6
- Fire resistance: EN11925-2
Thermal Conductivity

![Graph showing thermal conductivity vs density for different materials (SW, HW, TMP, Glass wool).]
Compression Strength

EN826 (at 10% deformation)
Bending Under Own Weight

ISOLE classification (Sliding sample over the table)
Water Retention Capacity

ISO17190-6 (Weighing sample before and after water immersion and centrifuge)
Ignitability Resistance

EN11925-2 (Ignitability of materials subjected to direct impingement of flame - Single Flame source test)
Sound Absorption

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Density</th>
<th>Grammage</th>
<th>Flow resistivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial glass wool</td>
<td>30</td>
<td>53</td>
<td>1585</td>
<td>27300</td>
</tr>
<tr>
<td>Foam formed pine pulp</td>
<td>30</td>
<td>42</td>
<td>1260</td>
<td>23600</td>
</tr>
</tbody>
</table>

Glass wool product

ISO 10534-2 (Impedance tube)
Conclusions

- Thermal conductivity of the foam-formed insulation panels based on paper-making pulps were at a minimum at density levels of 40-70 kg/m$^3$.
- The different pulp types induced fairly small differences in thermal conductivity values.
- In general, thermal conductivity of foam-formed materials was more or less comparable to commercial glass wool materials.
- The pulp properties and fibre dimensions significantly affected the mechanical properties of the panels.
- In general, foam-formed materials made from paper-making pulps can be categorised as semi-rigid thermal insulation materials.
- Mechanical properties, water absorption and fire resistance can be controlled with additives.
- Based on the results, these materials could be used as thermal insulation materials between rafters or in walls of wood construction or in internal partition walls.
Acknowledgements

- WoodWisdom-Net programme
- Tekes – the Finnish Funding Agency for Technology and Innovation
- Project partners and co-funding companies
TECHNOLOGY FOR BUSINESS