Wood shavings as insulating material for prefabricated low energy homes

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1. PROJECT

The Rosenheimer Haus Project was based on a co-operation between the Fachhochschule Rosenheim (University of applied science) and various industrial partners. The program was established to develop new concepts for the prefabricated house industry, emphasizing a total view at residential construction and domestic technology, concentrating on the ecological aspects. To find out about the utility and feasibility of the concepts three prefabricated houses were built in the Rosenheim area in winter '95/'96 (Fig.1). Walls, ceilings and roof were built of prefabricated panels in complete sections. In order to reach the high degree of ecology the Rosenheimer Haus was built using mostly wood and ecologically harmless materials. The panels were made of planked studs with wood shavings as pouring insulation. To ensure the harmlessness of the shavings in terms of settling and moisture behaviour, laboratory as well as field research was conducted.

2. MATERIAL AND METHODS

Huge quantities of wood shavings are produced in the woodworking industries and in planing mills. At present, this waste material is still mainly used for fuel. The idea to use wood shavings as a loose insulating material goes back a long way, but all attempts to use wood shavings for thermal insulation failed in the past due to the non-compliance with the severe German regulations. Not so long ago organic insulating materials were not allowed to be incorporated into building elements unless they were treated with not entirely harmless chemical additives. During the 'Rosenheimer Haus' project, wood shavings were successfully treated with non-hazardous additives to make them suitable for use as insulating material.

Raw material
Wood shavings are naturally produced in the plant while planing boards for exterior siding using an automatic moulding machine. Dry shavings are separated from all fine and coarse particles. Fig. 2 shows a sample of the separated shavings.

Processing
The material is treated in a continuous flow process by spraying a solution of soda and whey on it. After the treatment the shavings are dried again down to a moisture content of ∼12%. The addition of soda shifts the pH-value of the shavings into the alkaline range (pH=9) and thus protects them against fungi, while whey improves the resistance to fire. Both components can be considered as non-hazardous additives.

The prepared material is stored in a silo and is then transported on demand to the filling machine for the structural elements. The overall energy consumption for the processing of the shavings is 50 kWh/m³ which is very little in comparison to other insulating materials. Further developments of the processing will reduce the energy consumption in the future.

Characteristics
The following list shows the main characteristics of wood shavings as insulating material:

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<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (uncompressed shavings)</td>
<td>30 kgₐtro* /m³</td>
</tr>
<tr>
<td>Density in structural elements</td>
<td>60...90 kgₐtro* /m³</td>
</tr>
<tr>
<td>Moisture content of shavings in structural elements</td>
<td>12 % (related to mass)</td>
</tr>
<tr>
<td>Thermal conductivity (measured value)</td>
<td>0.04 W/mK</td>
</tr>
<tr>
<td>Thermal conductivity (according to registration)</td>
<td>0.045 W/mK</td>
</tr>
<tr>
<td>Water vapour permeability µ</td>
<td>1 / 2</td>
</tr>
<tr>
<td>Fire resistance classification</td>
<td>B2 (normal flammable)</td>
</tr>
<tr>
<td>pH- value</td>
<td>9</td>
</tr>
<tr>
<td>Endangering of fungi (according to DIN 40046)</td>
<td>almost zero</td>
</tr>
</tbody>
</table>

*) atro... absolutely dry

Basically wood shavings have a completely different moisture behaviour than traditional insulating materials such as mineral fibres. On one hand they are hygroscopic. Fig. 3 shows the sorption isotherms of raw and processed wood shavings in comparison to the isotherms of mineral fibres.

On the other hand even slightly compressed wood shavings tend to capillary water transport. The result of our own measurements with dense packed shavings showed that upon water impact, shavings absorb about 10 kg of water per m² in 2 hours. Without any further water contact the moisture spreads out deeper into the insulation layer and increases the moisture content in the affected area up to a critical point.

Every loose insulating material has the tendency to settle. So do the shavings. No long term documented research exists on the settling characteristics of wood shavings over time but short term laboratory research [1] shows that wood shavings compressed from a density of 30 kg/m³ to a density of 45 kg/m³ are safe from settling.

3. CONSTRUCTION OF STRUCTURAL ELEMENTS

All structural elements of the ‘Rosenheimer Häuser’ consist of prefabricated panels. They are in general built up by a supporting framework, sheathing on at least one side and insulation in the cavities between the studs or beams. The framework is made of solid wood (spruce/fir) or I-beams. The sheathing can be t&g spruce boards, plasterboard or gypsum bond fibre board. For thermal insulation treated and compressed wood shavings (cap.2) are used. Fig. 4 e.g. shows a cross-section of an outer wall of the ‘Rosenheimer Haus’.

All elements converging on the exterior must meet proper building requirements. Using wood shavings for thermal insulation impacts on some details of construction. These are shown in Fig. 5. The sheathing on the outside has to provide a weather tight shield. In case of water reaching through this layer there has to be another moisture barrier which prevents it from penetrating into the thermal insulation. Between the outer sheathing and the moisture barrier there is a 4 mm wide airspace. Small moulded openings in the outer sheathing cause a compensation of the vapour pressure and provide the wall with a high capacity to dry out. Moisture from inside the wall can emit quickly to the outside. To provide a vapour barrier on the inside, a layer of Kraft paper is attached to the framework.

The wood shavings in the cavities are mechanically compressed up to a density of ~70 kg/m³ to prevent them from settling. In comparison to the results of [1] this density exceeds the required compression. Measurements about thermal conductivity [2] show no significant decline of the insulation values at this grade of compression.

4. COURSE OF PROJECT, MEASUREMENT CONCEPT AND DATA RECORDING

After the planning of the buildings for the project, the elements were prefabricated at the plant of Baufritz GmbH & Co. and the three houses were built up in winter 1995/96 in the area near Rosenheim (Fig 1). The main differences between the houses were in the thickness of the walls and the technical equipment.

Several sensors and probes were integrated into the individual building elements to record data about temperature, humidity, moisture content, etc. In addition to that a weather station was installed on one of the houses to ensure weather data as a reference. Cables from all sensors and probes were connected to computers in a central room. Data was recorded
continuously for three years. During this period, the houses were uninhabited. Therefore, interior climate had to be artificially simulated to achieve equivalent basic conditions for evaluation of the recorded data.

One objective of the project was to find out about the behaviour of the wood shavings under practical conditions especially in terms of moisture behaviour and settling.

5. RESULTS

Moisture behaviour:
From the mass of data collected, some of the typical samples were selected and discussed. Fig. 6 shows the moisture conditions in the hygroscopic insulating material of the outer walls over the measure period. The average value of the moisture content remains close to the same level in every wall. With an average level of $\sim 11\%$ the south wall remains the driest one followed by the west wall, showing a value of $\sim 12.5\%$. The highest average moisture content of 14% was found in the north wall. At the inner and outer layers of the insulation, differences in the moisture conditions occurred during the year (Fig. 7). This can clearly be seen in the north wall. During winter time a distinct incline of the moisture content develops from the outer layer to the inner layer. Shavings on the outside became about 5% more humid, while shavings towards the interior dried by about the same percentage. At the south and west wall the influence of the sun is clearly recognizable. Over the year there are less moisture variations in the wood shavings. The higher rain load on the west wall has no effect on the moisture conditions of the wood shavings. The insulating material in the roof elements showed little variations. With an average moisture content of $\sim 10\%$ the wood shavings stay extraordinarily dry.

Data about the moisture content of the frame work resulted in values of 13%-15% with little variations during the period of measurement.

On the outer layer, the spruce boards exhibited moisture contents up to 30% on the north wall. Despite the average value of 20% moisture over 30 months, fungal attack was not apparent. Moisture levels on the other walls did not exceed the critical point of 20%.

Settling of wood shavings
In addition to [1], other experimental research tests were done in the laboratory in Rosenheim where the settling characteristics were examined under practical conditions. The most endangered sections for loose insulating material in terms of settling are situated within the walls. About 50 drill holes were made to receive information of the over-all settling of the wood shavings within the walls. In addition to that, three wall sections were opened after three years to examine the density of the material in different heights of the wall by using the gravimetric method. The results showed a roughly homogeneous density in all sections. $\sim 60\%$ of the borings did not show a settling at all. The maximum observed gap was 15 mm. The cause for settling behaviour like this was found in initial densities $\leq 60\text{kg/m}^3$ due to mistakes in the filling process in the plant. Most of the material settled during transport of the elements. Evidence of further settling occurring while the house was being studied could not be found.

6. CONCLUSION

The practical research on wood shavings as thermal insulation supported the proof of theoretical assumptions about their behaviour in terms of moisture conditions, thermal insulation as well as settling. The following statements can be made:

- Wood shavings are a very ecological and inexpensive insulating material. They are obtained by planing processes in the production of wood houses and so no special logistics are necessary.
- With a thermal conductivity of $\lambda = 0.045\text{W/m K} \ (0.040 \text{ W/m K})$ wood shavings can compete with other insulating materials.
- Wood shavings compressed to a density of $70\text{kg/m}^3$ are save from settling in walls up to 2.5 m.
- The construction of elements have to provide a reliable weather protection for insulation layer.
- The moisture contents of the wood shavings are $\leq 20\%$, thus there is no danger of fungi or damage by moisture.

7. REFERENCES

8. FIGURES

**Figure 1**
View at the ‘Rosenheimer Häuser’. Three houses with the same architectural concept and built of prefabricated panels. The houses vary in technical equipment and thickness of walls.

**Figure 2**
Sample of loose wood shavings from a planing machine. The bulk density is $\sim 30$ kg/m$^3$ at a moisture content of $\sim 12\%$ (related to mass).
Figure 3
Graph of Sorption for treated and raw wood shavings. In comparison the sorption reaction of mineral fibres is shown.
<table>
<thead>
<tr>
<th>No.</th>
<th>building material</th>
<th>thickness [mm]</th>
<th>density [kg/m³]</th>
<th>thermal conductivity [W/(mK)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>gypsum bond fibre board</td>
<td>25</td>
<td>1000</td>
<td>0.36</td>
</tr>
<tr>
<td>2</td>
<td>vapour barrier, $s_d = 2.3$ m</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3a</td>
<td>wood shavings for thermal insulation</td>
<td>320</td>
<td>80</td>
<td>0.055</td>
</tr>
<tr>
<td>3b</td>
<td>I-beam girder</td>
<td>320</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>moisture barrier, $s_d = 0.02$ m</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>air layer</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>T&amp;G spruce board</td>
<td>50</td>
<td>600</td>
<td>0.13</td>
</tr>
</tbody>
</table>

$U_{\text{average}} = 0.15$ W/(m²K)

**Figure 4**

Outer wall of the ‘Rosenheimer Haus’, type 2. With a 320 mm thick layer of wood shavings for thermal insulation the wall meets the requirements for the German ‘passive house standard’.
Construction of the outer wall with a high capacity to dry out. The outer sheathing has moulded openings. They cause a compensation of the vapour pressure of both sides of the outer layer. Moisture of the inside of the wall can emit extremely fast to the outside.

Figure 5
Figure 6
Moisture content of the thermal insulation during a 30 months period. The diagram shows the moisture content in three layers of the wood shaving insulation in % by weight of a south wall (top) and a north wall (bottom).
Figure 7
Typical course of moisture content in shavings of outer walls facing different directions, per summer and winter conditions. Moisture content in % by weight.
Figure 8
Examples for control drillings in the outer walls to determine the settling of the insulation material (1) house 3, south wall; 2) house 3, west wall)