(English Translation of Report from Josef Egle, Certified Engineer)

# "Holzwand 2020+"

A networking project for the ecological and energy-related development of marketable wood construction solutions for sustainable, resource-efficient structures of low and high energy standards

Sub-project
Scientific study of a new definition for the coefficient of thermal conductivity of solid wood construction elements, independent of building style

Status
Preliminary Report as of 03.07.2013

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1. <u>Current Technology</u>

In regards to the thermal conductivity, exterior construction elements made of solid wood show a completely different behavior compared to all other construction materials, like concrete, masonry, or steel. Due to its organic structure, wood is able to adjust its moisture content according to existing climatic conditions throughout its useful life (equilibrium moisture content). In the example of spruce wood and a climatic range between 20° / 30% relative humidity and 20° / 65% relative humidity, 1 $m^3$ of wood can absorb and release approximately 6000g = 6 l of water without damage.

Furthermore, a linear relationship exists between the thermal conductivity and the moisture content of wood: the dryer the wood is, the lower the thermal conductivity. See the following diagram.

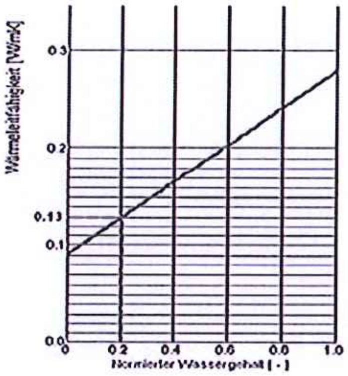



Diagram 1: thermal conductivity in spruce wood
vertical axis = thermal conductivity, watts per meter Kelvin
horizontal axis = standard moisture content
*Source: Fraunhofer Institit für Bauphysik*
*D- 83607 Holzkrichen*

Thermal conductivity of construction materials during heating periods of winter months is important for heat insulation. During this season, wood in heated building interiors shows a definite lower moisture content than in summer months. Exterior wall layers (for example, back-ventilated facades, insulation systems, etc.), which protect construction components of wood from direct weather conditions, also help to lower the moisture content of wood.

According to the respective European standards, particularly EN 12524:2000, structures made of coniferous wood like spruce, fir, pine, larch, etc. are to be measured with a lambda value of 0.13 W/mK , regardless of the building type. This value refers to a wood moisture content of 18-20%. For wooden structures in heated rooms and with exterior weather protection, the moisture content is expected be under 10% during heating periods. Therefore, the actual and efficient value of thermal conductivity in building practice lies significantly lower than 0.13 W/mK.

This deviation of the actual coefficient of thermal conductivity and the value in building practice is one of several causes for recurrent and clear differences between the calculated energy requirement needed for heating and the considerably lower actual energy consumption for buildings with a significant amount of solid wood elements. In a previous project, these related measurements and research were carried out at existing buildings. For the test object in Salzburg ,the actual measured consumption of energy for heating was 38.5% lower than the anticipated result, computed according to current regulations and standards. Over a 3-year study period, a similar result was observed for residential buildings, which were built between 2004 and 2006. The actual energy consumption level was 39.5% lower than the calculated consumption value.

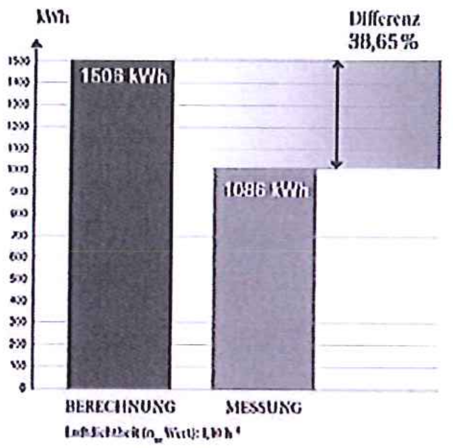



Diagram 2: Test buildings with homogenous log walls 200 mm thick, period of measurement= 74 days 19.11.2010 to 02.02.2011
Berechnung = calculated (kilowatt hours)
Messung = actual measurement

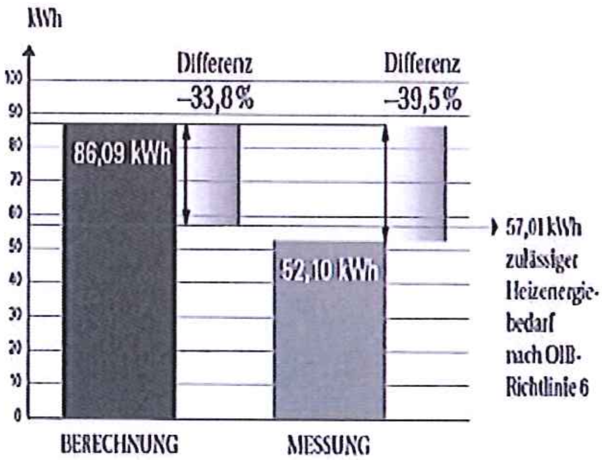



Diagram 3: residential and office buildings built 2004 - 2006 heating energy over a 3-year period

57.01 kWh allowable energy requirement for heating per OIB guideline 6

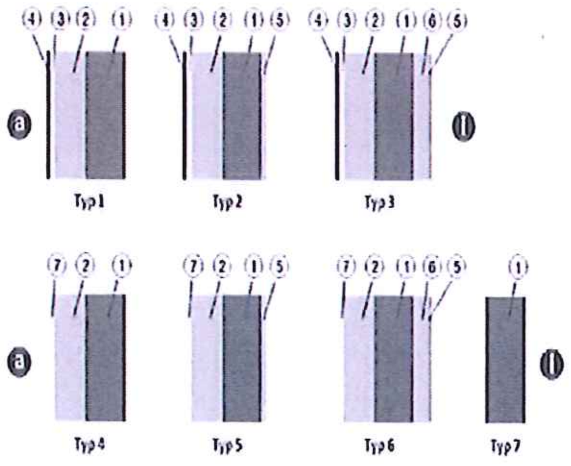
2. Project Tasks and Goals (information not provided)

3. <u>Project Team and Responsibilities</u> (not translated)

| Aufgabenverteilung | Projektteam |
|---|---|
| Antragsteller / Rechnungsadresse | Verein zur Förderung des Salzburger Zimmererhandwerkes<br>Obmann-Stv. Fritz Egger, Obmann Josef Koch |
| Kooperationsmanagement | Salzburger Holzbau, Balthasar Promegger |
| Projektmanagement<br>Postzustelladresse und –verteilung<br>Kontoerstellung und Betreuung | Holzcluster Salzburg<br>Herbert Lechner / Lisa Maria Griesebner |
| Förderantrag | Land Salzburg, Walter Haas<br>Wirtschafts- und Innovationsförderung |
| Wissenschaftliche Arbeiten | Egle Engineering, Josef Egle |
| Laboruntersuchungen Wärme-leitzahlen | BOKU Wien, Alfred Teischinger |

4. <u>Matrix of Wall Types</u>

The project team devised a matrix of 7 different construction types based on a wall core of wood. This wall could contain an exterior side with either back ventilation or a ventilated outer formwork (types 1 - 3), or a thermal insulation system (types 4 - 6). The room side of the wall differs between a plaster finish or plasterboard panel, as well as an installation layer. Type 7 is the special form, consisting of a homogenous solid wood exterior wall. For wall types 1 - 6, solid wood panel systems were primarily studied and a few buildings included wood frame construction.




<u>Wall Layers</u>: a = outer side i = inner side
1 = wood core
2= exterior insulation
3 = ventilated layer
4 = outer formwork
5 = plaster/gypsum finish
6 = installation layer
7 = exterior plaster finish

Diagram 4: Matrix of types of wall structures with wood construction, basis for selection of test objects (buildings)

## 5. Test Buildings

In addition to the different construction types, buildings in various climates and altitudes within the state of Salzburg were selected for this study. The regional distribution of these test buildings can be seen on the map to the right.

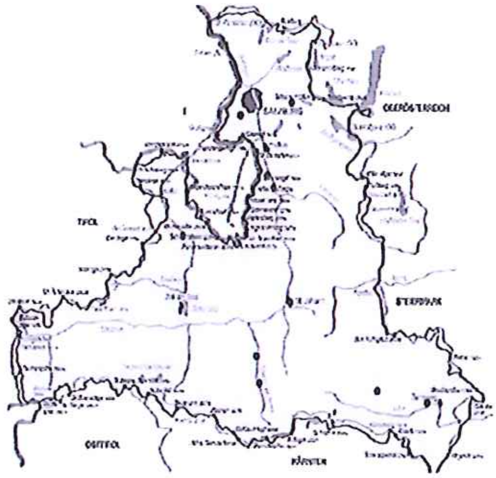


Diagram 5: Map of the state of Salzburg with locations of test buildings

## 6. Measurement Process

Long-term electrodes were installed in the test buildings to capture the moisture content values of the wood, according to the electrical resistance method. After numerous pretests and comparative measurements round stainless steel rods (V2A) with a diameter of 4mm were selected as the test electrodes. The front end was sharpened to a tip of 10 mm in length using CNC-processing. The shaft diameter was shaved to a size of 3 mm. The mid-section of the electrode was covered with a non-conductive shrink tubing made of plastic, similarly found in the electrical trade. Following an adequate heating up of the shrink tubing, it encased the shaft securely. The final thickness of the insulated shaft was between 3.6 and 3.8 mm.

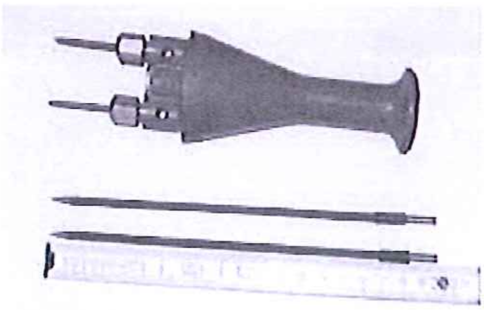


Diagram 6: Example of an electrode pair before assembly. Ram-in electrode GANN M18 used for marking the electrode spacing on the wood surface.

To avoid additional friction while inserting the electrodes, a hole was drilled into the wood with a drill bit diameter of 5 mm. The depth of the hole was 15-20 mm shorter than the electrode. In this way, it was ensured that the tip of the electrode had contact to the wood upon impaction. The space between the electrode pair is 28 mm according to the dimensions of the GANN measuring device. Pre-marking of its position on the surface of the wood element was done with the aid of the GANN ram-in electrode M18. The complete length of the electrodes was set according to the respective thickness of the wood. The shaft end remains attainable on the room side of the wood surface to carry out regular measurements with alligator clamps.

In each case, the long term measurements occurred in heated rooms, which displayed "normal" room temperatures during heating periods. Where possible, the locations of the measurements at each test building were taken on all four cardinal directions.

According to specifications, the measurement of the wood moisture content was done once a week. In addition to the moisture measurements, the room air temperature and relative room humidity values were collected in each test building using a climate data logger type TFA 3015. The first analysis of this climate data has not been completed as per the date of this report.

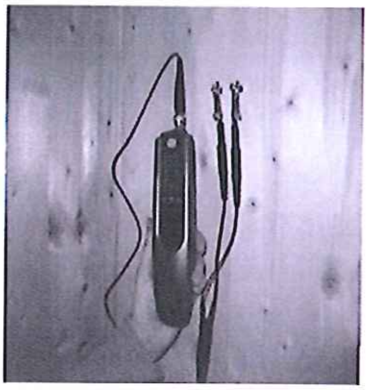


Diagram 7: Example of measurement of wood moisture content. Use of alligator clamps for the ram-in electrodes. Displayed moisture value = 8.3%

7. <u>Results to Date</u>

The attached table 1 includes the average value of moisture content of wood for 15 test buildings studied from 01.01.2013 to 31.05.2013 with varying cardinal directions.

The results can be summarized as follows:

a) During the winter months, the relevant timeframe for the calculation of thermal energy requirements, an average value for the moisture content of wood of approximately 8 % is assumed.

b) Within the 7 selected construction types there are no significant differences in the wood moisture content.

c) Initially, an elevated, however gradually declining wood moisture content in solid wood exterior walls could be observed for those built in 2012 (on-going drying phase).

d) No significant differences can be seen in flat wood panel elements in relation to the assembly methods of the individual construction layers to one another (with adhesives, use of mechanical connecting materials, wood to wood connections).

e) All test buildings show regularities in relation to the orientation of the studied construction elements. The south side provided the lowest wood moisture content, the north side, the highest value.

## 8. Evaluation of the Results and Outlook

The fact, that back-ventilated systems and those with heating insulation systems roughly yield the same wood moisture content values during the heating period, is surprising. Back-ventilated systems would be expected to provide a quite lower wood moisture content than thermal insulation systems.

Similar findings apply to the comparison with solid wood walls, which are visible from the room side and have systems with an inner room finish or installation layer. In this situation, a somewhat lower wood moisture content for visible constructions was expected as well.

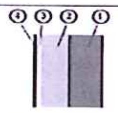
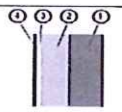
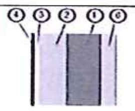
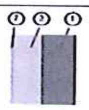
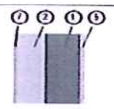
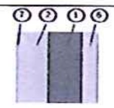
For the study of the thermal conductivity of wood occurring in building practice, a reference moisture value should be set at 8%.

The original approach for the project was to investigate the coefficient of thermal conductivity in wood, dependent upon the construction type. After reviewing the available results to date, this approach can be reduced to a uniform treatment of all building types. There is no differentiation required between solid wood panel systems and wood frame construction.

For the currently prepared laboratory measurements of test samples, a controlled climate for weight consistency can be recommended that corresponds to a reference moisture level of 8%.

## 9. Table 1

This table lists the test buildings according to their corresponding wall type (left). Information to the right includes: test building/object number, type of building, location, wood construction type (Platte = solid wood panel HRB = wood frame construction), and average value of wood moisture content (Mittelwert) determined during the timeframe from 01.01.2013 through 31.05.2013

| | | |
|---|---|---|
| Typ 1 |  | Objekt Nr.5, Wohnhaus, 5630 Bad Hofgastein, Platte, Mittelwert 8,39%<br>Objekt Nr. 11, Kindergarten, 5585 Unternberg, Platte, Mittelwert 6,68% |
| Typ 2 |  | Objekt Nr. 1, Wohnhaus, 5322 Hof b. Salzburg, Platte, Mittelwert 8,39% |
| Typ 3 |  | Objekt Nr. 3, Wohnhaus, 5632 Dorfgastein, HRB, Mittelwert 8,29%<br>Objekt Nr. 4, Wohnhaus, 5632 Dorfgastein, HRB, Mittelwert 7,37%<br>Objekt Nr. 12, Wohnhaus, 5440 Golling, Mittelwert 8,22% |
| Typ 4 |  | Objekt Nr. 10, Kindergarten, 5585 Unternberg, Platte, Mittelwert 7,83%<br>Objekt Nr. 6, Gewerbebau, 5760 Saalfelden, Platte, Mittelwert 9,63%<br>Objekt Nr. 13, Wohnhaus, 5620 Schwarzach, Platte, Mittelwert 8,69% |
| Typ 5 |  | Objekt Nr. 8, Lehrbauhof, HRB, Mittelwert 7,26%<br>Objekt Nr. 14, Wohnhaus, 5431 Kuchl, Platte, Mittelwert 7,18% |
| Typ 6 |  | Objekt Nr. 2, Wohnhaus, 5632 Dorfgastein, HRB, Mittelwert 8,22% |
| Typ 7 |  | Objekt Nr. 7, Lehrbauhof, Platte, Mittelwert 7,47%<br>Objekt Nr. 9, Wohnhaus, 5570 Mauterndorf, Platte, Mittelwert 7,96% |