Modelling the knot taper in Scots pine (Pinus sylvestris L.) from terrestrial laser scanning - derived branch attributes

Pyörälä, Jiri Kristian

Tallinn University of Technology
2019

Pyörälä , J K , Tonteri , O , Rikala , J P , Sipi , M H , Holopainen , M E & Hyyppä , J 2019 , Modelling the knot taper in Scots pine (Pinus sylvestris L.) from terrestrial laser scanning - derived branch attributes . in H Kallakas (ed.) , Proceedings of the 14th annual meeting of the Northern European Network for Wood Science and Engineering (WSE2018) . Tallinn University of Technology , Tallinn , pp. 22-24 , Northern European Network for Wood Science and Engineering (WSE) , Tallinna , Estonia , 02/10/2018 .

http://hdl.handle.net/10138/304946

unspecified
publishedVersion

Proceedings of the 14th annual meeting of the

Northern European Network for Wood Science and Engineering (WSE2018)

October 2-3, 2018
Tallinn, Estonia

Edited by
Heikko Kallakas
Tallinn University of Technology

Title

Proceedings of the 14th annual meeting of the Northern European Network for Wood Science and Engineering (WSE2018)

Scientific Committee

Magnus Wålinder (Sweden)
Erik Larnøy (Norway)
Marketta Sipi (Finland)
Jaan Kers (Estonia)
Bruno Andersons (Latvia)
Dan Ridley Ellis (Northern UK)
Emil Engelund Thybring (Denmark)
Kristina Ukvalbergienė (Lithuania)
Christian Brischke (Northern Germany)
Bartolomej Mazela (Poland)

Local organizer

Tallinn University of Technology, Laboratory of Wood Technology

Local organising committee

Triinu Poltimäe (Chairman)
Heikko Kallakas
Karmo Kiiman
Villu Kukk
Jaan Kers

Sponsors

SNS Nordic Forest Research

TAL TECH

EMPL EESTI METSA- JA PUIDUTÖÖSTUSE LIIT

Estonian Timber

PREFACE

The Northern European Network for Wood Science and Engineering (WSE) initiated its annual meetings in 2005. It has in the last 12 years matured into an invaluable forum for researchers in all aspects of wood science and engineering to meet and share knowledge. The importance of this meeting is undeniable, especially for young researchers who get a chance to present their work, exchange know-how and experience, and expand their network with fellow wood scientists in the WSE region. On behalf of the organising committee, we would like to thank Nordic Forestry Research (SNS) for their financial contributions to WSE2018.

List of previous WSE meetings
2005 Honne, Norway
2006 Stockholm, Sweden
2007 Helsinki, Finland
2008 Riga, Latvia
2009 Copenhagen, Denmark
2010 Tallinn, Estonia
2011 Oslo, Norway
2012 Kauna, Lithuania
2013 Hannover, Germnay
2014 Edinburgh, United Kingdom
2015 Poznan, Poland
2016 Riga, Latvia
2017 Copenhagen, Denmark

We are really glad to welcome you at the 14th Meeting in Tallinn.

Tallinn, September 2018
Jaan Kers, Triinu Poltimäe and Heikko Kallakas

LIST OF CONTENTS

WOOD PRODUCTS IN THE CONTEXT OF VOC REGULATIONS

Authos: Dr. Martin Ohlmeyer

About the corresponding (presenting) author

MARTIN OHLMEYER

WWW.THUENEN.DE

MARTIN.OHLMEYER@THUENEN.DE
+49 40 73963-635

MOTIVATION

People spend 80 to 90% of their time indoors. Therefore, the quality of the indoor air is of particular interest. Human wellbeing is not only affected by the climatic conditions (temperature, air humidity, air exchange rate and air velocity) but also by the concentrations of volatile organic compounds (VOC). Sources of these VOCs might be building materials, floor coverings, interior furnishings, furniture, human activities (including cooking, cleaning, renovating, smoking) or the outside air.

The current focus is on building materials, as these, typically, cannot be influenced by the resident. Thus, these materials are particularly noteworthy for their VOC delivery. For wood products, this is of fundamental importance, as wood as an organic material can contain a number of substances that are volatile under normal conditions and thus detectable as VOC concentrations - the typical smell of pine wood is one of them.

LEGAL FRAMEWORK

Products in Europe

The European Construction Products Regulation (EU CPR, 2011) places seven essential requirements on buildings. These include hygienic precautions regarding the release of toxic and other VOC substances into indoor air. In order to implement this requirement, it is envisaged that this property of construction products will be declared under the CE marking. In recent years, a horizontal test standard which was published in January 2018 was developed for this purpose: This EN 16516 regulates the test conditions and the presentation of the results with regard to the intended use of the product.

The principle testing procedure is based on the ISO 16000 series, but several specifications are added in order to improve the testing quality and reliability. Furthermore, the intended use of the products to be evaluated is considered based on a “reference room” (3 x 4 x 2.5 m = 30 m^3) under defined climate conditions. The testing results are calculated and expressed according to the intended use: e.g., for floor panels with a loading factor of L = (3 x 4 m^2) / 30 m3 = 0.4 m^2/m^3, considering a constant ventilation rate n = 0.5 h^{-1}, the area specific ventilation rate is q = 1.25. The tests shall be performed with this factor q for flooring products.

This standard describes the horizontal standardized assessment methods for the harmonized approaches relating to dangerous substances under the Construction Products Directive, but the evaluation and classification of the final results is not given.

However, there is still a set of rules for the evaluation of the results for the implementation. For some time now, this has been the subject of discussion and coordination by the EU Commission (under the leadership of DG Growth) and should be implemented as a Delegated Act. So far, it has only been decided that different criteria should be evaluated (CMR substances, formaldehyde and VOC substances) and that there will be at least two classes for each substance, with the higher class always being an open class. Thus, the extent to which one of these characteristics is relevant for the individual market can be regulated at the national level. This relevance must be considered.

As an example, the reference to the already existing regulation for formaldehyde is given here: For formaldehyde emissions two classes E1 and E2 are listed in the CE standard for wood materials (EN 13986), whereby in Germany only E1 is permitted due to the ChemVerbV (2017).

Once this ordinance for VOC has been enacted by the Delegated Act, the next step, via the harmonized CE standards, will be to introduce mandatory evaluation of VOCs for the relevant products across Europe. At the moment, however, the status on the Delegated Act is still open. It is not possible to predict at this time when the status is expected to be established.

After the implementation of EN 16516 and the VOC classification within the CE-marking of building products, the system of testing and evaluating VOC emissions will be established. The decision about which of the classes will be applicable or suitable will be taken on the individual national level. Consequently, although the testing and evaluation is harmonised, there might be different products which can be used in several countries.

Products in Germany

Until 2016, the Deutsches Institut für Bautechnik (DIBt, Centre of Competence for Construction) based the AgBB (2018) scheme on the building inspectorate approval of certain building products (floor coverings). According to the European Court of Justice, no national rules may be stricter rules than those of the European Union. Consequently, the further application of this practice has been discontinued.

Currently, the requirements of the AgBB scheme are part of the MVV TB, Appendix 8, (2017) and shall be applied to the following products from January 2019 on:

- Floor coverings and constructions
- Parquets and wooden floors
- Sports flooring
- Surface coatings for wooden floors and resilient floor coverings
- Treated or glued woods
- Subsequently applied organic fire-retardants.

Different criteria (VOC, R value, SVOC, CMR) are examined as part of the assessment. The decisive difference to the European approach, however, is that according to this assessment a product is either suitable for application or not - there is no grading or classification.

In order to ensure a sufficiently precise reproducibility and thus the load capacity of the measurement results, product-specific requirements for the test according to EN 16516 are necessary, since this test method is to be used for all building materials with different characteristics. These requirements are to be developed and defined by the CEN product TCs as part of the CE-marking. No stipulations have yet been made in the con-text of the MVV TB, so it is currently not possible to determine under which preconditions (i.e., the time of testing, degree of loading, possibly pre-treatment) the above-mentioned conditions.

In addition, there are a number of labels (e.g., Blauer Engel, Natureplus) which are awarded under private-business rules and are used for marketing purposes.

WHAT DO WE KNOW ABOUT WOOD?

Wood is an organic material that - like almost all organic materials - emits volatile organic compounds (VOCs). Typical substances in this case are (a) primary emissions which are freely present in the wood (e.g., terpenes which are responsible for the characteristic odour of different softwoods) or (b) secondary emissions which can arise, for example, from the geochemical substance as reaction products (e.g., organic acids from hardwoods). Formaldehyde is also emitted in very small amounts of wood (around and up to 10 $\mu g/m^3$) (Boehme 2000).

Woods with a high content of volatile constituents emit the largest amounts of VOC: these include the softwoods and, in particular, the pine trees (*Pinus sylvestris*); the most notable substances are terpenes (mainly α-pinene), aldehyde and organic acids. Spruce (*Picea abies*) emits almost the same substances, but typically in much less concentrations. The most important hardwoods, such as beech (*Fagus sylvatica*), birch (*Betulus*) and oak (*Quercus*), emit almost exclusively organic acids (mainly acetic acid) in significant concentration (Riisholm-Sundman 1998, Steckel et al 2013).

The measured magnitudes of VOCs can vary greatly (up to one order of magnitude) as they are affected by several factors:

Extract content, which in turn may be affected by genetics, site conditions and calamities

- Core and sapwood content
- Processing conditions: temperature, material moisture, pH value, degree of comminution, etc.

Therefore, the same substances can usually be recovered from wood-based materials in the VOC spectrum, because they are also found in the woods from which the wood-based materials were produced - but typically of a different amount and composition (Ohlmeyer 2008).

REFERENCES

AgBB (2018). Requirements for the Indoor Air Quality in Buildings: Health- related Evaluation Procedure for Emissions of Volatile Organic Compounds (VVOC, VOC and SVOC) from Building Products. Committee for Health-related Evaluation of Building Products, August 2018 https://www.umweltbundesamt.de/sites/default/files/medien/355/dokumente/agbb_evaluation_scheme_2018_1.pdf Version current as of 2018-09-10

Boehme, C. (2000). Über die Formaldehydabgabe von Holz und ihre Veränderung wäh-rend technischer Prozesse der Holzwerkstoffherstellung, Dissertation, Univ. Göttingen

ChemVerbotsV (2017). Verordnung über Verbote und Beschränkungen des Inverkehr-bringens und über die Abgabe bestimmter Stoffe, Gemische und Erzeugnisse nach dem Chemikaliengesetz. German Law. www.gesetze-im-internet.de/chemverbotsv_2017/ Version current as of 2018-09-10

EN 13986+A1:2005. Wood-based panels for use in construction - Characteristics, eval-uation of conformity and marking.

EN 16516:2017. Construction products — Assessment of release of dangerous substanc-es — Determination of emissions into indoor air.

EU CPR (2011). Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of con-struction products and repealing Council Directive 89/106/EEC.

MVV TB (2017). Muster-Verwaltungsvorschrift Technische Baubestimmungen. http://www.dibt.de/de/geschaeftsfelder/data/MVV_TB.pdf Version current as of 2018-09-10

Ohlmeyer, M. (2008). Influencing parameters on the emissions of volatile organic compounds from OSB. 9th Pacific Rim Bio-Based Composites Symposium. Rotorua, New Zealand. 5-8 November 2008

Risholm-Sundman, M., Lundgren, M., Vestin, E. and Herder P. (1998). Emissions of acetic acid and other volatile organic compound of different species of solid wood. Holz als Roh- und Werkstoff, 56, 125-129

Steckel, V., Knöpfle, A. and Ohlmeyer, M. (2013). Effects of climatic test parame-ters on acetic acid emission from beech (Fagus sylvatica L.). Holzforschung, 67, 47–51

HOW FUNGAL DECAY AFFECTS ELECTRICAL WOOD MOISTURE CONTENT MEASUREMENTS

Authors: Christian Brischke*, Simon Stricker, Linda Meyer-Veltrup and Lukas Emmerich

CHRISTIAN BRISCHKE

WWW.HOLZ.UNI-GOETTINGEN.DE

christian.brischke@uni-goettingen.de
+49 551 39 29514

MOTIVATION

Moisture plays a key role in the enzymatic degradation of wood by decay fungi. Therefore, automated moisture content (MC) monitoring provides valuable information about the moisture-induced risk of decay and can serve as an early warning system before decay occurs. The most common systems for this purpose are based on measuring the electrical resistance of wood. The electrical resistance is dependent on wood MC, but also on temperature, wood species, electrode configuration, and the number and mobility of ions in wood. Therefore, material-specific resistance characteristics are needed to reliably interpret the resistance data and final MC measurements. Fungal decay itself can have a threefold effect on resistance –based MC measurements: 1.) Metabolization of cell wall substance usually comes along with a change of the sorption properties, 2.) Decay fungi potentially change the electrical conductivity of wood due to translocation of ions and enhancing their mobility, and 3.) Fungi are actively transporting water to the location of enzymatic activity. All these mechanisms are not necessarily rectified, might interfere with each other and are likely dependent on the different rot types. The aim of this study was therefore to systematically examine the effect of brown and white rot decay on the sorptive and electrical properties of soft- and hardwood.

EXPERIMENTAL

Specimens (35 (ax.) x 10 x 10 mm^3) made from Scots pine sapwood (*Pinus sylvestris* L.) and European beech (*Fagus sylvatica* L.) were incubated with *Coniophora puteana* and *Trametes versicolor* and harvested at weekly intervals between one and twelve weeks. After incubation the specimens were oven-dried and remoistened to target MC of 5, 8, 10, 12, 15, 16, 18, 25, 40, 50, 60 and 70 %. Mass loss (ML) and MC were determined gravimetrically. Electrical resistance (R) was determined after harvesting before and after oven-drying and re-moistening. Within the hygroscopic range the specimens were conditioned above different saturated salt solutions; beyond the fiber saturation point they were vacuum-pressure impregnated in demineralized water and afterwards dried to target MC. Sorption isotherms were determined using a Dynamic Vapor Sorption (DVS) apparatus and comparative gravimetric and resistance-based MC measurements were conducted.

RESULTS & DISCUSSION

Brown and white rot decay reduced EMC increasingly with increasing relative humidity (RH). For instance, at 20°C/65 %RH brown rot reduced EMC by 0.02 %MC/%ML, while it was 0.09 %MC/%ML at 20 °C/95% RH.

At a given EMC below fiber saturation both, brown and white rot decay, led to a decrease in R. In Fig. 1 R is correlated with EMC separately for groups of specimens representing 10%-intervals of ML by fungal decay. The increase in electrical conductivity can be explained by the reduction of sorption sites such as free hydroxyl groups leading to longer jump distances for ions which are increasing their mobility (Du 1991). Furthermore, the number and concentration of charge carriers is assumed to be increased since fungi transport ions to the location of enzymatic activity (Shortle 1982, Ostrofsky et al. 1997). Finally, low-molecular acids are formed, which lower the pH and consequently increase electric conductivity (Mäkelä et al. 2002, Green III and Clausen 2013). However, unexpectedly white and brown rot decay decreased R of wood to the same extent (Fig. 1).

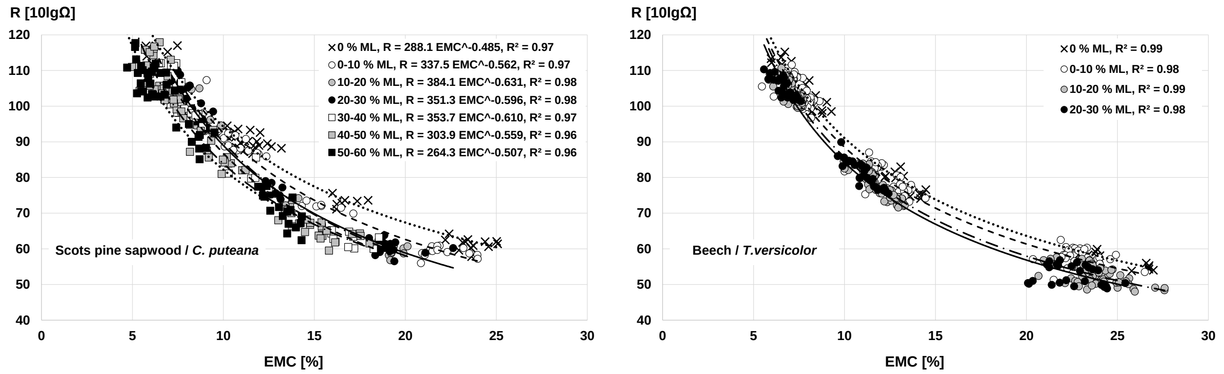


Figure 1. Relationship between electrical resistance R and gravimetrically determined EMC in the hygroscopic range for different mass loss (ML) intervals.

In the over-hygroscopic range (Fig. 2) the R remained almost unaffected by MC at a given ML between approximately 30 and 80 % MC, but differed significantly between different ML. Interestingly, R increased with increasing ML caused by brown rot decay, but decreased with ML due to white rot decay. In addition to an increased amount of ions, the increased conductivity of decayed wood above fiber saturation compared to sound wood might be explained by a higher absolute amount of water in decayed wood. The fungal mycelium itself obviously serves as conductor as previously reported by Kirker et al. (2016) and shown in this study for both white and brown rot decayed wood (Fig. 2).

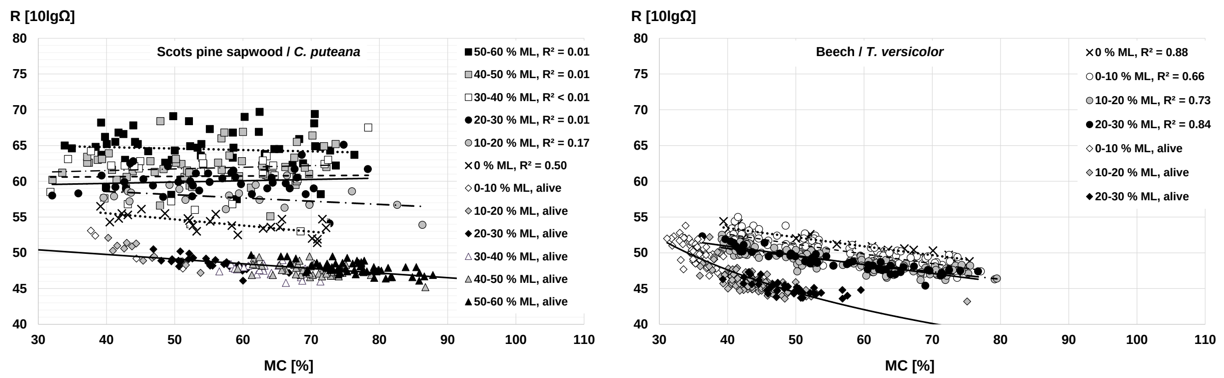


Figure 2. Relationship between electrical resistance R and gravimetrically determined MC in the overhygroscopic range for different mass loss ML intervals. Additional R measurements directly after harvest of incubated specimens when fungal mycelium was still alive.

CONCLUSIONS

Brown and white rot decay significantly reduced the sorption of wood, but living mycelia in decaying wood is increasing its MC. The effect of decay on the electrical resistance differed between white and brown rot and between the hygroscopic and the over-hygroscopic range. If electrical resistance based measurements are applied to monitor the wood MC and the moisture-induced risk for decay within wooden components, decay itself has the potential for adulterating the results. In the hygroscopic range occurrence of decay leads to an overestimation of wood MC, while the latter is dramatically underestimated above the FSP. Such effects were observed only for decayed wood, which was afterwards sterilized through oven-drying and re-wetted to various MCs below and above the FSP. In contrast, specimens containing still living mycelium showed MC only well above FSP and an increased R compared to undecayed wood at the same MC. In practice, decayed wood is rather seldom re-dried in a way that the fungus inside dried to death and re-wetted afterwards. More likely, decay fungi actively keep the moisture level they need to survive inside the substrate. Even though partly drastic errors in measurement were found due to decay, the effect of fungal decay appears negligible for monitoring the moisture-induced risk of decay. Contrary to this, the increase in electrical conductivity due to the presence of fungal mycelium within the wood amplifies the signal in terms of increased MC.

REFERENCES

Du, Q.P. (1991). *Einfluss holzartenspezifischer Eigenschaften auf die elektrische Leitfähigkeit wichtiger Handelshölzer.* Doctoral thesis. University Hamburg, Department Biology, Hamburg.

Green III, F., Clausen, C.A. (2003). Copper tolerance of brown-rot fungi: time course of oxalic acid production. *International Biodeterioration Biodegradation,* 51, pp. 145-149.

Kirker, G.T., Bishell, A.B., Zelinka, S.L. (2016). Electrical properties of wood colonized by *Gloeophyllum trabeum*. *International Biodeterioration Biodegradation,* 114, pp. 110-115.

Mäkelä, M., Galkin, S., Hatakka, A., Lundell, T. (2002). Production of organic acids and oxalate decarboxylase in lignin-degrading white rot fungi. *Enzymatic Microbiological Technology,* 30, pp. 542-549.

Ostrofsky, A., Jellison, J., Smith, K.T., Shortle, W.C. (1997). Changes in cation concentrations in red spruce wood decayed by brown rot and white rot fungi. *Canadian Journal of Forestry Research,* 27, pp. 567-571.

Shortle, W.C. (1982). Decaying Douglas-fir wood: ionization associated with resistance to a pulsed electric current. *Wood Science*, 15, pp. 29-32.

MOISTURE SORPTION AS IT OUGHT TO BE: A CRİTİCAL RE-EVALUATİON OF THE PARALLEL EXPONENTİAL KİNETİCS MODEL

Authors: Emil E. Thybring *, Charles R. Boardman, Samuel V. Glass, Samuel L. Zelinka

EMIL ENGELUND THYBRING

WWW.KU.DK

EET@IGN.KU.DK; +45 35334433

MOTIVATION

Following the rapid adoption of automated sorption balances (often referred to as «dynamic vapor sorption» or «DVS» analysers) a large number of studies have been published in the past ten years on the water vapor sorption kinetics in wood, cellulose, and other biopolymers. Nearly all of these papers use the parallel exponential kinetics model (the so called "PEK" model) to fit the kinetic data, see Figure 1. Empirically it has been shown that the PEK model results in high R^2 values when fit to sorption data. Theoretically, the fitting parameters from the PEK model have been used to describe many different wood phenomena including the location of sorption sites, the monolayer moisture content, activation energies, and viscoelastic properties of the wood cell wall. In this paper, we closely examine how the PEK model fit parameters depend upon the method used to collect sorption data and whether these parameters can be physically meaningful.

EXPERIMENTAL

Sorption kinetic data were collected at 25 °C with an IGAsorp gravimetric vapor sorption analyzer (Hiden Isochema, Warrington, UK). Samples of 20 mg of two different cellulosic materials were used: loblolly pine (*Pinus taeda*) and commercial microcrystalline cellulose (MCC). In a typical experiment, the sample was exposed to a step of either 5 % RH or 10 % RH in the range 0-95 % RH. At a given RH, measurements were continued to "equilibrium" which was defined as the change in mass being less than the slight fluctuations in observed mass of an inert sample. In previous work, this mass stability limit of the instrument was found to be at most 2 µg over a 24 hour period [1]. Therefore, measurements were continued until the change in mass was less than 2 µg over 24 hours; for the 20 mg samples, this represented a dM/dt of 0.07 µg g^{-1} min^{-1}.

RESULTS & DISCUSSION

Despite the many physical interpretations derived from PEK analyses, upon careful examination, it can be shown that the parameters from the PEK model cannot have physical significance, but instead are just fitting parameters. We base this claim off of the following evidence: (1) the time constants of the PEK model depend upon data collection time, i.e. the measurement "hold time"; (2) there are non-random patterns in the residuals of the PEK model fit, see Fig. 2; (3) different curve fitting methods give different time constants and in some cases the differences are significant and show patterns; and (4) when the kinetic data are reanalyzed with Multi-Exponential DEcay Analysis (MEDEA) fitting a continuous spectrum of exponentials to the data by use of a Non-Negative Least Squares (NNLS) algorithm, in most cases more than two time constants are found.

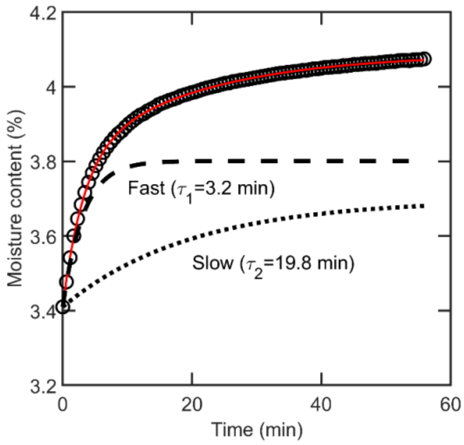


Fig. 1 Moisture content of MCC in absorption from 20% to 30% RH as a function of time (circles), PEK model fit (solid curve), and separated curves for fast and slow processes.

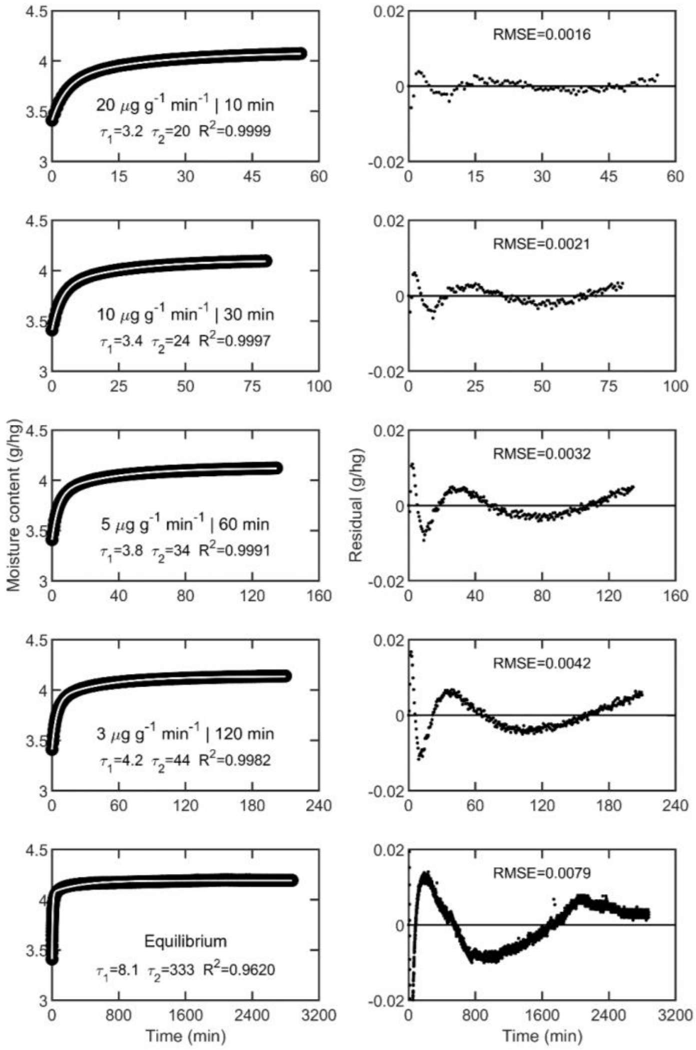


Fig. 2 (left) Moisture content of MCC in absorption from 20% to 30% RH as function of time, with PEK model fits overlaid (white curves) for various stop criteria. Inset text shows τ (min) and coefficient of determination from PEK model fit. (right) Residuals of the fit.

CONCLUSIONS

The PEK model cannot capture the actual sorption curve form. PEK model parameters depend not only on the mass change criterion that controls measurement hold time, but also on RH level making even qualitative comparisons of a single sample across RH steps meaningless. Physically meaningful properties cannot be derived with the PEK model from water vapor sorption measurements. Consequently, using the PEK model to explore properties of cellulosic materials interacting with water is not recommended.

REFERENCES

[1] Glass, S.V., Boardman, C.R., Thybring, E.E., and Zelinka, S.L. (2018) Quantifying and reducing errors in equilibrium moisture content measurements with dynamic vapor sorption (DVS) experiments, Wood Science and Technology, 52(4), pp. 909-927. https://doi.org/10.1007/s00226-018-1007-0

WATCHING WOOD DRY: CHARACTERISING WATER IN WOOD BASED ON DESORPTION OR SCANNING ISOTHERMS?

Authors: Maria Fredriksson* and Emil Engelund Thybring

About the corresponding (presenting) author:

MARIA FREDRIKSSON

www.byggnadsmaterial.lth.se

maria.fredriksson@byggtek.lth.se;

+46 46 222 74 12

MOTIVATION

Water plays an important role in degradation processes of wood and influences physical wood properties such as dimensional stability and mechanical behaviour. The interaction between water and wood has therefore been widely studied and this is commonly done by determining sorption isotherms. Sorption isotherms show the relation between the equilibrium moisture content and the ambient relative humidity (RH). The equilibrium moisture content is however not only dependent on the ambient climate, but also on the moisture history of the sample; the moisture content is higher if equilibrium is reached by desorption than if equilibrium is reached by absorption (Pidgeon and Maass 1930). This is called sorption hysteresis and is observed in most porous materials. It is thus important to consider the moisture history of the specimen when determining sorption isotherms. After the introduction of automated sorption balances (Williams 1995), it has become common to determine sorption isotherms by initially drying the sample and then measure the absorption isotherm up to a high RH, typically 95% RH, see e.g. (Hill et al. 2009; Ceylan et al. 2014; Himmel and Mai 2015). Thereafter, desorption is initiated from this high RH and the sample is dried in steps back to 0% RH again. This procedure of measurement does however not yield desorption isotherms, but scanning isotherms. In the present study, the consequences of this procedure of measurement on the obtained sorption isotherms and the evaluated sorption hysteresis are shown.

EXPERIMENTAL

Sorption isotherms were determined for Norway spruce (*Picea abies* (L.) Karst.) in a sorption balance (DVS Advantage, Surface Measurement Systems Ltd., London). All measurements started with specimens that had been vacuum saturated with water. A specimen was placed in the sorption balance and the desorption isotherm was determined by exposing the specimen to the following relative humidity levels: 95-80-65-50-35-0%. The absorption isotherm up to 95% RH was then determined followed by a scanning desorption isotherm from 95% RH, both using the same RH levels as for desorption. This measurement was repeated twice. For two other specimens, the desorption isotherm was determined as described above, but the absorption isotherms were determined up to 80% RH and scanning desorption was subsequently initiated from 80% RH. For more details, see Fredriksson and Thybring (2018). Sorption isotherms and sorption hysteresis were evaluated. The latter was evaluated as absolute difference in moisture content between the absorption isotherm and the desorption and scanning isotherms respectively.

RESULTS & DISCUSSION

The average sorption isotherms and absolute sorption hysteresis are shown in Figure 1. As expected, the desorption isotherm was higher than the scanning isotherms initiated from 95% and 80% RH reached by absorption. To clarify the reasons for this, the hygroscopic sorption isotherms are placed in the context of the full sorption isotherm for Norway spruce in Figure 2. Here it is seen that for the wood to follow the desorption isotherm, an initial moisture content substantially higher than the equilibrium moisture content at 95% RH reached by absorption is needed due to the large sorption hysteresis. From Figure 1 it is also seen that when sorption hysteresis was evaluated from desorption and absorption isotherms, the hysteresis was linear unlike when hysteresis was evaluated from absorption and scanning isotherms. The shape of the hysteresis curve consequently depends on the moisture content from which desorption was initiated. This needs to be considered when interpreting the underlying mechanisms of sorption hysteresis based on hysteresis curves.

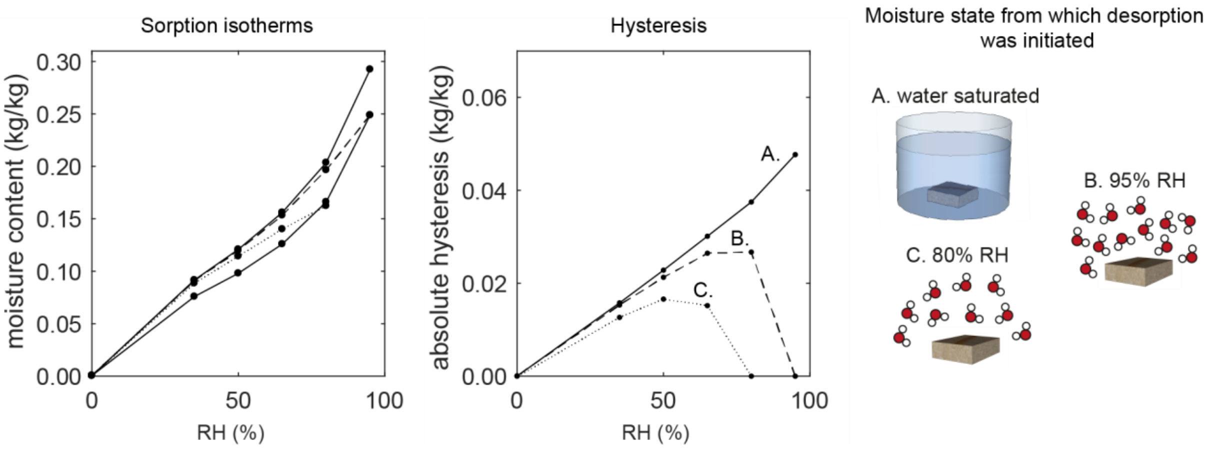


Figure 1. Average sorption isotherms and absolute sorption hysteresis evaluated from absorption and desorption isotherms (A), absorption and scanning isotherm from 95% RH (B) and absorption and scanning isotherms from 80% RH (C).

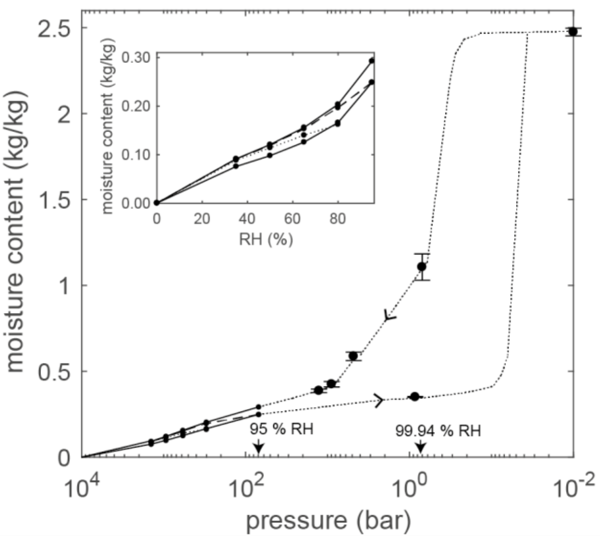


Figure 2. Full sorption isotherm for Norway spruce (*Picea abies* L. Karst.), over-hygroscopic sorption isotherm data from Fredriksson and Johansson (2016).

CONCLUSIONS

Determination of true desorption isotherms require initially water saturated specimens; desorption initiated from all other moisture states will generate scanning isotherms. The currently most common procedure of measurement thus underestimates the desorption isotherm. In addition, the initial moisture state of the specimen is important to consider when studying sorption hysteresis since more complex hysteresis patterns are obtained when using scanning isotherms instead of desorption isotherms which may make the interpretation of underlying mechanisms of sorption hysteresis more challenging.

REFERENCES

Ceylan, Ö., Goubet, F. and De Clerck, K. (2014). Dynamic moisture sorption behavior of cotton fibers with natural brown pigments. *Cellulose* 21(3): 1149-1161.

Fredriksson, M. and Johansson, P. (2016). A method for determination of absorption isotherms at high relative humidity levels: measurements on lime-silica brick and Norway spruce (*Picea abies* (L.) Karst.). *Drying Technology* 34(1): 132-141.

Fredriksson, M. and Thybring, E. E. (2018). Scanning or desorption isotherms? Characterising sorption hysteresis of wood. *Cellulose* published online.

Hill, C. A. S., Norton, A. and Newman, G. (2009). The water vapor sorption behavior of natural fibres. *Journal of Applied Polymer Science* 112: 1524-1537.

Himmel, S. and Mai, C. (2015). Effects of acetylation and formalization on the dynamic water vapor sorption behavior of wood. *Holzforschung* 69(5): 633.

Pidgeon, L. M. and Maass, O. (1930). The adsorption of water by wood. *Journal of the American Chemical Society* 52(3): 1053-1069.

Williams, D. R. (1995). The characterisation of powders by gravimetric water vapour sorption. *Int. LABMATE* 20(6): 40-42.

MODELLING OF WOOD RESISTANCE-TYPE MOISTURE METERS IN WOOD MOISTURE CONTENTS ABOVE THE FIBRE SATURATION POINT

Authors: Hannes Tamme*and Valdek Tamme

*hannes.tamme@student.emu.ee

MOTIVATION

Modelling starting position – description of the current situation [1]:

- "... an indicated MC-reading is more or less a rough guess" (Ressel 2006) and that "readings greater than 30% must be considered only qualitative" (Bergman 2010, Wood Handbook).
- Also Brookhuis (brookhuis 2009) stated that "Measurements below 7% and above the wood fibre saturation point are not accurate. For a precise determination beyond the measuring range, we recommend using the oven-dry method"
- ASTM D4444 – 2005 stated that ´´Meter scales … do not imply reliability of readings above the fibre saturation point´´

EXPERIMENTAL

For modelling resistance-type moisture meters, which have been calibrated by the manufacturer, in moisture contents above the fibre saturation point or, in other words, for more accurate recalibration in this moisture range, specimens made of black alder, silver birch and common aspen with dimensions 100 x 60 x 60 mm (length x width x thickness) were used. The experiments made use of resistance-type moisture meters like Gann HT 85T, FMD-6 and NDT James manufactured by leading companies. A total of approximately 1,300 single measurements were carried out, on the basis of which nine calibration models were prepared.

2.1. Modelling starting position – standards:
How does the standard ISO/IEC 98 – 3:2008(E) "Uncertainty of measurement" describe the calibration function and evaluation types of measurement uncertainty? The standard sets out two types for evaluating measurement uncertainty:
Type A evaluation of measurement uncertainty.
Type A evaluation method is widely used for statistical analysing and modelling measurements obtained with so-called non-destructive methods.
According to the standard ISO/IEC 98 – 3:2008, type B evaluation of measurement uncertainty dominates in the case of strict (upon strong correlation between variables Y and X) calibration, although also elements of type A evaluation are used. In the case of type B evaluation, it is common to proceed from a calibration certificate determined on the basis of a reference or from a natural law, or both.

RESULTS & DISCUSSION

Table 1. Results of testing of moisture meters on black alder specimens

Statistical parameter	Oven dry actual MC %	Moisture meter readings		
		Gann HT 85T (MC %)	NDT James (MC %)	FMD – 6 (MC %)
Range 1	68.6 – 124.8	32.6 – 39.2	30.4 – 33.3	29.8 – 33.5
Range 1, mean	105.7	35.9	31.6	31.8
Range 1, st. dev.	12.154	1.299	0.819	0.908
Range 2	52.7 – 65.5	26.8 – 30.9	25.4 – 30.7	26.4 – 28.7
Range 2, mean	59.5	28.6	27.7	27.4
Range 2, st. dev.	3.66	1.104	1.259	0.577
Range 3	27.3 – 37	19.9 – 23.8	23 – 29	21.4 – 24.7
Range 3, mean	31.56	21.8	25.6	23.1
Range 3, st. dev.	2.031	0.793	1.52	0.718

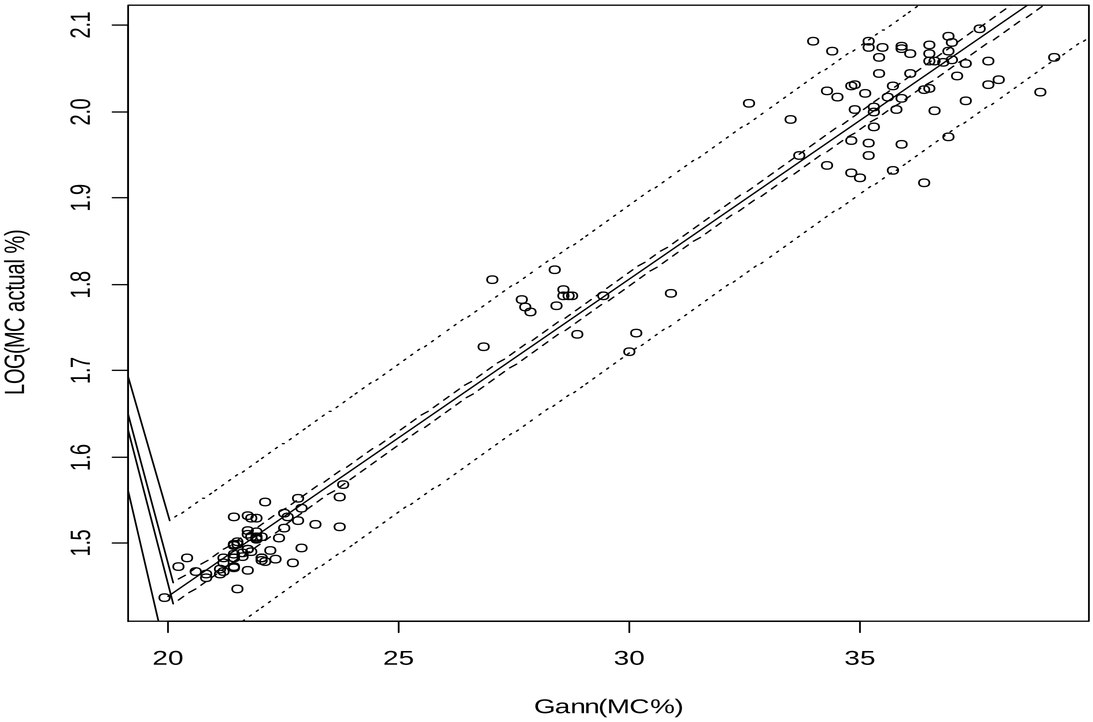


Figure 1. Regression line of testing wood moisture meter Gann HT 85T on black alder specimens with –their 95% confidence and tolerance bands.

CONCLUSIONS

- In the moisture content range "unfavourable" (that is, above 30% MC) for resistance-type moisture meters, quantitative evaluation of moisture content was preferred over purely qualitative evaluation by applying *in situ* calibration or modelling typical of "non-destructive methods".
- Regression results and regression diagnostics for three deciduous tree species (black alder, birch and aspen) and three types of moisture meters are available in tables 4, 5, and 6 in Tamme *et al*. 2014. [1]
- More information on problems with calibrating resistance-type wood moisture meters in moisture contents above the wood fibre saturation point can be found in Valdek Tamme's PhD thesis (2016) "Development of resistance-type control methods for wood drying". [2]

REFERENCES

[1] Tamme, V., Muiste, P.,Padari, A., Tamme, H. 2014. Modelling of Resistance –Type Wood Moisture Meters for Three Deciduos Tree Species (black Alder, Birch, Aspen) in Moisture Contents Above Fibre Saturation Point. Baltic Forestry, 20 (1): 157 – 166.

[2] Tamme, Valdek 2016. Development of resistance-type control methods for wood drying, PhD thesis, Kuma Print, Tartu, Estonia, 135 pp.

MODELLING THE KNOT TAPER IN SCOTS PINE (*PINUS SYLVESTRIS* L.) FROM TERRESTRIAL LASER SCANNING - DERIVED BRANCH ATTRIBUTES

Authors: Jiri Pyörälä*, Okko Tonteri, Juha Rikala, Marketta Sipi, Markus Holopainen, Juha Hyyppä

JIRI PYÖRÄLÄ

WWW.HELSINKI.FI

JIRI.PYORALA@HELSINKI.FI

MOTIVATION

Three-dimensional (3-D) sawing simulation is expected to become a standard tool in the future sawmill wood procurement planning to promote more precise and sustainable use of forest resources [1]. The method requires realistic virtual 3-D sawlogs as inputs, and currently the absence of interior knot structure information introduces inaccuracy to the pre-harvest simulations. As a solution, individual knot shapes can be modelled from the exterior branch attributes [2]. However, the required branching data are difficult to obtain from standing timber.

Terrestrial laser scanning (TLS) can acquire detailed 3-D point cloud data from a forest environment [3]. These data enable the reconstruction of branching structures in individual trees [4]. Here, we calibrated a knot taper equation for individual knots using TLS data of exterior stem and branching attributes. Our aim was to study the feasibilities of TLS producing realistic sawlog models with interior knot structure information for pre-harvest sawing simulation.

EXPERIMENTAL

We acquired the materials in May 2017 from a homogeneous Scots pine (*Pinus sylvestris* L.) stand in Evo, Southern Finland, selecting ten trees with 18–34 cm diameter-at-breast-height. The TLS data were collected using a Faro Focus X^{3D} 330 (Faro Technologies Inc., FL, USA) phase-shift scanner, and processed following the methods described in Pyörälä et al. [4].

The trees were harvested and sawn through-and-through. Knot locations and diameters were recorded manually for all knots on the board surfaces. The data were split to modelling and validation data sets. We expressed the knot diameters as exponential functions of the distance from the stem pith, and smoothed the estimated model parameters using multiple regression with respect to height and TLS-derived stem and branch diameters. We used the smoothed parameters to predict the knot diameters from the validation TLS data, and compared the mean value of the knot diameter predictions with the mean value of the knot diameter references in similar locations.

RESULTS & DISCUSSION

Figure 1 illustrates examples of knot diameter predictions. The comparison to the manual references indicated that predicted mean knot diameters had 0.38 cm root-mean-squared error and 0.15 cm bias. Table 1 shows the method tended to overestimate the knot diameters in the dead crown, and underestimate them towards the stem surface within the live crown. This was likely due to the predictions relying on a low number of detected branches in either extreme, a result of the self-pruning in the former and the increasing scanner-distance and foliage occlusion in the latter.

In addition to the branch-specific calibration approach [2] as examined in this study, previous research has successfully expressed the knot tapering as a stem diameter-dependent function using a chronosequence of branch measurements [5,6]. Collecting TLS-data from comparable stands of varying age could enable building more complete modelling databases for the prediction of knot properties. Such database could be used to account for the occluded knots, and to replace the destructive reference measurements.

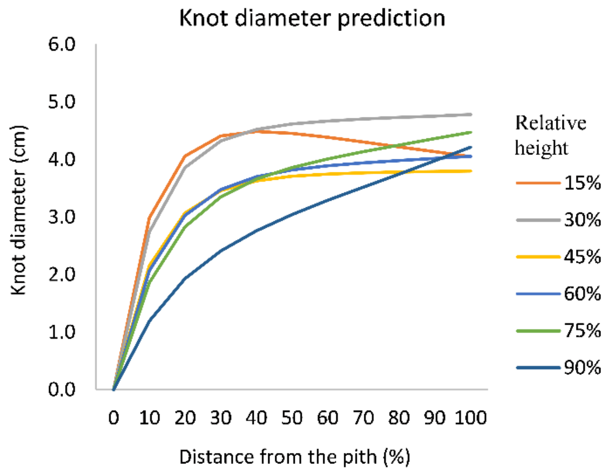


Figure 1. An example of predicted knot diameters from stem pith (0%) to stem surface (100%) at varying heights relative to the tree height, indicated by the line colours (0% = stump height, 100% = tree height).

Table 1. The knot diameter prediction bias (cm) in comparison to the manual knot references: The rows correspond to the binned relative height (0% = stump height, 100% = tree height), and columns to the binned relative distance from the pith (0% = stem pith, 100% = stem surface). Green and red cell colours indicate whether the method over- or underestimated the knot diameters, respectively.

Relative height (%)	Relative distance from the stem pith (%)									
	10	20	30	40	50	60	70	80	90	100
15	0.19	0.65	0.59	0.59	0.63	0.77	0.89	0.82	-0.22	
20	0.67	0.41	0.28	0.37	0.38	0.42	0.60	0.46	1.04	0.23
25		0.15	0.40	0.09	0.05	0.10	0.16	0.19	0.73	0.32
30	-0.05	0.33	0.65	0.54	0.37	0.45	0.74	0.40	0.63	0.43
35	0.28	0.09	0.40	0.04	0.41	-0.21	0.23	0.40	0.40	0.94
40	-0.23	0.60	0.47	0.07	0.32	0.21	0.25	-0.01	0.23	0.05
45	0.32	0.09	0.28	0.03	-0.20	0.04	-0.35	-0.05	-0.05	-1.10
50	0.47	0.25	0.20	-0.18	-0.16	-0.02	-0.17	-0.26	-0.27	-0.37
55	-0.11	0.14	0.36	0.18	-0.02	0.19	-0.18	0.02	-0.61	-0.33
60		-0.12	0.36	0.21	-0.06	0.26	0.00	-0.18	-0.62	-0.67
65		0.45	0.26	0.44	0.12	0.11	0.35	0.15	0.35	-0.31
70		0.27	0.06	0.22	0.14	0.08	-0.16	-0.20	-0.15	0.27
75		0.96	0.10	0.36	0.18	-0.26	-0.75	0.06	-0.33	-0.25
80		0.25			0.37	-0.65	-0.37	-0.19	-0.51	-0.03

CONCLUSIONS

Our experiment suggested that the knot diameters in any given location within the stem can be estimated accurately using external stem and branch attributes derived from TLS point clouds, but only if the branches are visible and detected correctly. The feasibility of the presented approach to estimate knot structures for sawing simulations is thus currently limited. However, using a chronosequence of TLS - branch measurements across various stands remains to be explored.

REFERENCES

[1] Auty, D., Achim, A., Bédard, P., and Pothier, D. (2014). StatSAW: modelling lumber product assortment using zero-inflated Poisson regression. Canadian Journal of Forest Research, 44(6), pp. 638-647.

[2] Duchateau, E., Longuetaud, F., Mothe, F., Ung, C., Auty, D., and Achim, A. (2013). Modelling knot morphology as a function of external tree and branch attributes. Canadian Journal of Forest Research, 43(3), pp. 266-277.

[3] Liang, X., Kankare, V., Hyyppä, J., Wang, Y., Kukko, A., Haggrén, H., Yu, X., Kaartinen, H., Jaakkola, A., and Guan, F. (2016). Terrestrial laser scanning in forest inventories. ISPRS Journal of Photogrammetry and Remote Sensing, 115(1), pp. 63-77.

[4] Pyörälä, J., Liang, X., Vastaranta, M., Saarinen, N., Kankare, V., Wang, Y., Holopainen, M., and Hyyppä, J. (2018). Quantitative assessment of Scots pine (Pinus sylvestris L.) whorl structure in a forest environment using terrestrial laser scanning. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 11(9), In Press.

[5] Osborne, N.L. and Maguire, D.A. (2015). Modeling knot geometry from branch angles in Douglas-fir (Pseudotsuga menziesii). Canadian Journal of Forest Research, 46(2), pp. 215-224.

[6] Mäkinen, H. and Mäkelä, A. (2003). Predicting basal area of Scots pine branches. Forest Ecology and Management, 179(1-3), pp. 351-362.

USABILITY OF MORFI COMPACT FIBRE ANALYZER IN TRACHEIDS MEASUREMENT

Authors: Marta Górska[1], Edward Roszyk[2]

About the corresponding (presenting) author:

Poznań University of Life Sciences

Faculty of Wood Technology

Department of Wood Science

Poznań, Poland

marta.gorska@up.poznan.pl

+48 61 848 7450

MOTIVATION

Tracheids length as a predominant conifers cells type is an important determiner of many wood properties (e.g. wood strength). Commonly used tracheids length evaluation method involve maceration and then measuring by using microscope equipped with camera as well as computer microscope image analyzer. The main weakness of this conventional measuring way is time-consuming. The possible improvement may come from MorFi Compact Fiber and Shive Analyzer. This modern device enable to measure not only length of fibrous elements but also many others dimensional properties (Przybysz and Przybysz, 2016). It is effectively applied in paper industry, wood, rapeseed (González et al., 2013), hemp (Barbera, 2011) or bamboo pulp (Ma et al., 2011), providing complex analysis of the pulp. Achieving data is very quick and measurement reliability is satisfying. In this study an attempt has been made to apply MorFi Compact into the basic research of wood and some findings of the experiment have been presented.

EXPERIMENTAL

Scots pine (*Pinus sylvestris* L.) wood from copper mining area has been investigated. The 20-year old tree has been fallen and 1.5 cm thick slice was sampled. Every single radial increment has been splitted and then early- and latewood separated. Extracted samples have been macerated by treating in temperature of 60°C with a concentrated acetic acid and hydrogen peroxide mixture in 1:1 proportion. Samples were all neutralized and observed under the microscope. From every annual increment 30 cells were selected and measured for both earlywood and latewood. Afterward the same macerated xylem samples were analysed with MorFi Compact device. Macerates were water-downed according to device's requirements. Concentration of suspension is automatically evaluated but suggested concentration is 0.04 g/dm^3. For each sample approximately 5000 tracheids have been analyzed at the same time. The core of the analysis is a series of photos taken by the embedded camera. Performing a single test took below 3 minutes.

RESULTS & DISCUSSION

Scots pine tracheids are normally 1.8-4.5 mm long (Kokociński, 2005), whereas cells of the examined wood are much shorter and about 1.03 mm (microscopic measurements for both early- and latewood). Tracheids' dimensions are primarily determined by genetic constitution, but they can be altered by external factors such as precipitation, insolation and soil condition or environment contamination (Kozłowski and Pallardy, 1997). The last reason could occur in the case of this study because the ground on which the examined tree was growing was flotation tailing extremely polluted by heavy metals.

Data collected in microscopic measurements have been compared with analogous results provided by MorFi Compact device (Fig 1.).

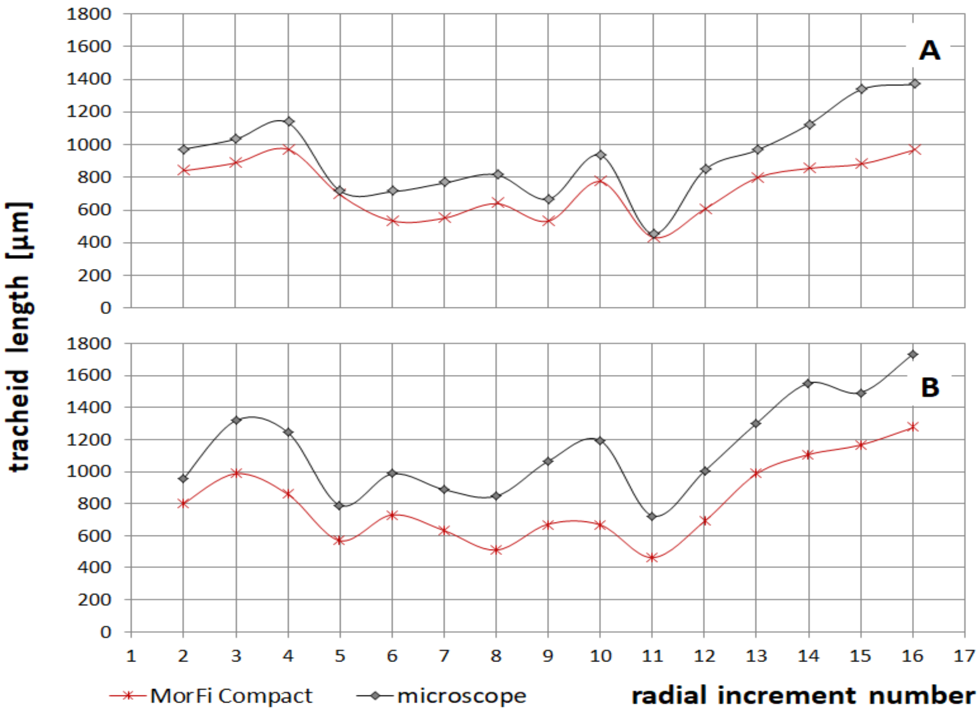


Figure 1. Average arithmetical tracheid length measured for earlywood (A) and latewood (B)

Records from the MorFi Compact device appeared to be lower on average by 20 % for earlywood and by 30% respectively for latewood. The explanation may be that during microscopic analysing it is possible to select any single tracheid excluding cells broken in the process of sampling and to estimate whether there is early- or latewood tracheid. The analyzer by contrast does not exclude broken tracheids or non-tracheid cells. Although the minimum threshold of 200 µm of object length has been set, broken tracheids longer than this could still affect the results. Moreover, in some samples latewood may have not been precisely separated which also influenced the results.

CONCLUSIONS

Data provided by MorFi Compact tend to be downsided, but the profile is still comparable to that of the microscopic measurements. There is probably some possibility to adjust records by finding a good correction coefficient which would provide authentic results, but it is not an easy task. Nonetheless, sometimes methods which are not very precise but provide results in a short time prove more useful than very accurate methods which requires more time. However, in basic measurements exactness is an essential attribute.

ACKNOWLEDGEMENTS

The authors are grateful to the Natural Fibres Advanced Technologies laboratory in Lubraniec for allowing to use MorFi Compact device for the measurements.

REFERENCES

Barbera, L., Pelach, M. A., Perez, I., Puig, J., & Mutje, P. (2011). *Upgrading of hemp core for papermaking purposes by means of organosolv process*. Industrial Crops and Products, 34(1), 865-872.

González, I., Alcalá, M., Arbat, G., Vilaseca, F., & Mutjè, P. (2013). *Suitability of rapeseed chemithermomechanical pulp as raw material in papermaking*. BioResources, 8(2), 1697-1708.

Kokociński, W. (2005). *Anatomia drewna*, Poznań: Prodruk.

Kozłowski T.T., Pallardy S.G. (1997). *Physiology of Woody Plants*. 3rd ed. USA: Elsevier, 138-139.

Ma, X., Huang, L., Chen, Y., & Chen, L. (2011). *Preparation of bamboo dissolving pulp for textile production; Part 1. Study on prehydrolysis of green bamboo for producing dissolving pulp*. BioResources, 6(2), 1428-1439.

Przybysz, K., Przybysz, K. (2016). *Evaluation of dimensional properties of cellulosic fibers as a tool for swift, initial evaluation of papermaking potential of pulp*. Annals of Warsaw University of Life Sciences Forestry and Wood Technology (No 96), Warsaw University of Life Sciences Press, 22-25.

CHARACTERISATION OF BROWN-ROT MODIFIED LIGNIN FROM NORWAY SPRUCE

Authors: Gry Alfredsen*, Nicole Labbé, Isabella Børja, Olav Hegnar, Keonhee Kim, Sigrun Kolstad, Eva Grodås, Monica Fongen, Søren Talbro Barsberg, Janka Dibdiakova

GRY ALFREDSEN

WWW.NIBIO.NO

ALG@NIBIO.NO; +4791876568

MOTIVATION

Brown-rotted lignins have been found to undergo extensive modifications of the native lignin including oxidative demethylation, side chain oxidation, depolymerisation and repolymerisation (Eastwood et al., 2011; Riley et al., 2014) and are reported to be a highly recalcitrant component of forest soils (Meentemeyer, 1978; Berg and Staff 1980). One of the aims of NIBIO's strategic biotransformation project is to study lignin modification by brown-rot fungi, with the ultimate goal to utilize the properties of the modified lignin to make high value products. Few studies have so far focused on brown-rot modified lignins, and those available used shorter incubation time than the present study. The aim of this study was to: 1) to develop a fractional separation method using a dimethyl sulfoxide/lithium chloride (DMSO/LiCl) dissolution system to isolate both native lignins from non-decayed wood and modified lignins from brown-rot decayed wood, 2) present preliminary lignin characterisation data from Norway spruce decayed for 1 year by brown-rot monocultures.

EXPERIMENTAL

Norway spruce (*Picea abies*) was milled and the 500-1000 µm fraction was used in these experiments. The autoclaved wood was added to Petri dishes and inoculated with 5 ml liquid inoculum (4% malt solution + *Rhodonia placenta* or *Gloeophyllum trabeum*) per gram wood (n = 3). To achieve fully decayed wood, the samples were incubated for 1 year. In addition, severely brown-rot decayed *P. abies* wood from nature was collected (mainly decayed by *Fomitopsis pinicola*) (n = 3).

Py-GCMS lignin characterisation

The samples were air dried for 7 days and weight measured. Then the samples were extracted with deionised water and ethanol utilizing a solvent extraction system. Fourier transform infrared spectroscopy (FT-IR) and Pyrolysis Gas Chromatography Mass Spectrometry (Py-GC/MS) were employed to assess chemical changes in the extracted samples. Principal component analysis (PCA) was performed on the PyGC/MS data to compare the different treatments.

Dissolution and separation of lignin by DMSO/LiCl

The milled wood powder (40-mesh sieve) was extracted with 90% (v/v) acetone/water in a Soxhlet apparatus for 24 h. The extractives-free wood powder was dried under vacuum then ball milled for 15 min at 300 rpm. DMSO/LiCl was added to the fine powder under firm stirring for 2 h then ethanol was added followed by rotavapor evaporation. The isolated lignin fractions were characterized using FT-IR.

RESULTS & DISCUSSION

Py-GCMS lignin characterisation

The lignin fractions were classified as mainly guaiacyl-syringyl lignin type: mainly composed of guaiacyl (G) units with noticeable amounts of syringyl (S) units and fewer p-hydroxyphenyl (H) units. The molar ratio of syringyl units to non-condensed guaiacyl units to (S/G) slightly increased after brown-rot monoculture decay and in the severely brown-rot decayed wood from nature (Table 1). PCA of the PyGC/MS data showed clear separation: between the brown-rot decayed monoculture samples and control (Figure 1A), between brown-rot decay from nature and control (data not shown), and between the two brown-rot monocultures (Figure 1B).

Table 1. Results of Py-GCMS adjusted with a correction factor (Sykes et al., 2009).

Test material	H Lignin %	G Lignin %	S Lignin %	Total Lignin %	S/G ratio
Control (no fungal decay)	0.4 (0.0)	28.7 (1.5)	1.5 (0.0)	30.6 (1.5)	0.05 (0.00)
R. placenta (monoculture - 1 year)	0.8 (0.1)	52.3 (4.0)	3.2 (0.3)	56.3 (4.4)	0.06 (0.00)
G. trabeum (monoculture - 1 year)	0.7 (0.1)	49.9 (0.6)	3.3 (0.0)	53.9 (0.5)	0.07 (0.00)
F. pinicola (mix of organisms in nature)	1.7 (0.3)	67.4 (10.7)	5.0 (1.1)	74.2 (12.0)	0.07 (0.00)

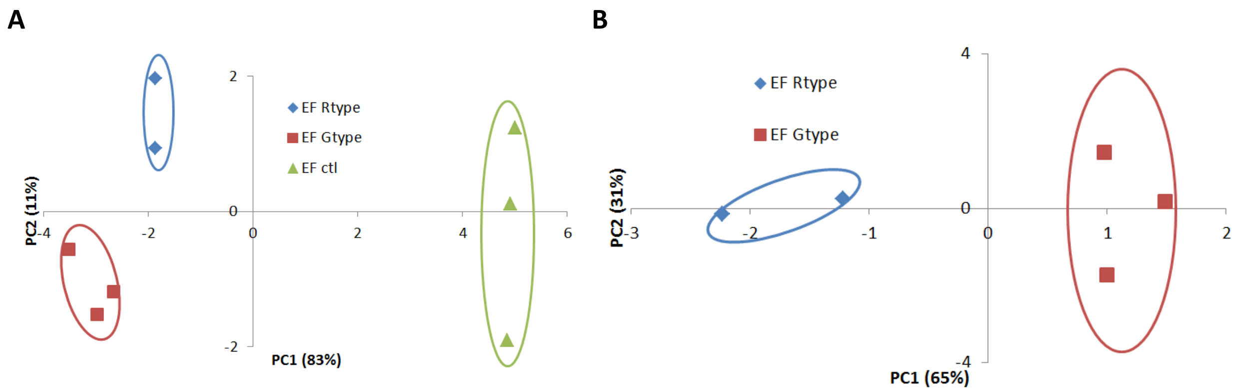


Figure 1. Py-GC/MS PCA scores plots of: A. *G. trabeum* (blue) and *R. placenta* (red) decayed *P. abies* wood vs. control (green), B. *R. placenta* decayed wood (blue) vs. *G. trabeum* decayed wood (red).

FT-IR spectra of lignin fractions after DMSO/LiCl treatment

Figure 2 illustrates the FT-IR spectra of *P. abies* lignin fractions extracted using DMSO/LiCl to sample weight ratios of 0.4:1 (spectrum L2), 0.6:1 (spectrum L4) and 0.8:1 (spectrum L6). The relative intensities of the bands for aromatic skeleton vibrations, assigned at 1597, 1506, 1460, and 1421 cm^{-1} were rather similar. This implies that the method did not change the lignin structure between fractions. No intense polysaccharide bands were observed in the spectra, which imply that the method was successful in removing carbohydrates. The characteristic of G-S lignins type isolated by this method was in accordance with the lignin classification system by Faix (1991). The intensity of the band at 1506 cm^{-1} was higher than that of the band at 1460 cm^{-1} as well as with a maximum intensity around at 1125 cm^{-1}. In general, G-lignins type showed a maximum band at 1140 cm^{-1} while a few percent S units in lignin was enough to change the maximum peak from 1140 cm^{-1} to a wave number below 1128 cm^{-1}. Hence, these G and S unit findings are proof of concept of the method. The method will also be tested on brown-rot decayed wood (data not shown).

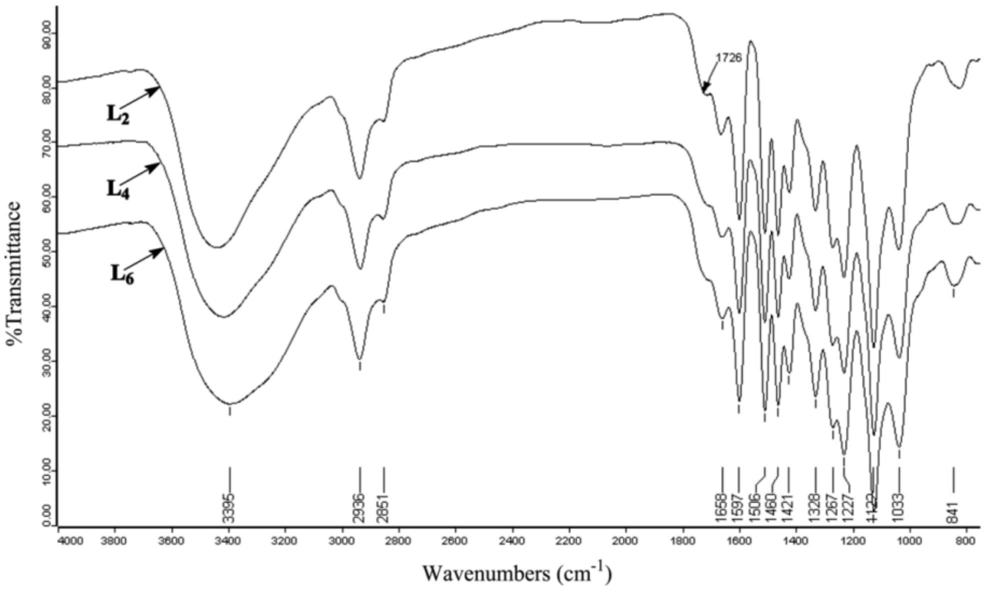


Figure 2. FT-IR spectra of lignin preparations of weight ratios L2, L4, and L6 from *P. abies*.

CONCLUSIONS

Py-GC/MS data showed that: 1) the molar S/G lignin ratio slightly increased after brown-rot monoculture decay and in the severely decayed wood from nature, 2) PCA showed clear separation between the brown-rot decayed samples and control, and between the two brown-rot monocultures.

FT-IR spectra of isolated lignin fractions obtained after DMSO/LiCl treatment of *P. abies* wood were mainly composed of guaiacyl units combined with noticeable amounts of syringyl units. Moreover, it was noteworthy that the separated lignins contained only trace amounts of associated polysaccharides. Based on these results this novel method seems to be a proper method for lignin isolation.

REFERENCES

Berg, B. and Staaf, H. (1980). Decomposition rate and chemical changes of Scots pine litter. II. Influence of chemical composition. *Ecological Bulletin*, 32, pp. 373-390.

Eastwood, D.C., Floudas, D., Binder, M. et al. (2011). The plant cell wall–decomposing machinery underlies the functional diversity of forest fungi. *Science*, 333(6043), pp. 762-765.

Faix, O. (1991). Classification of lignins from different botanical origins by FT-IR spectroscopy. *Holzforschung*, 45, pp. 21–27.

Meentemeyer, V. (1978). Macroclimate and lignin control on litter decomposition rates. *Ecology*, 59 pp. 465-472.

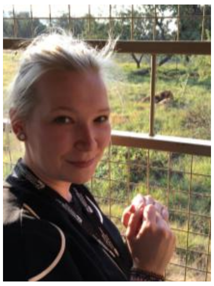
Riley, R., Salamov, A.A., Brown, D.W. et al. (2014). Extensive sampling of basidiomycete genomes demonstrates inadequacy of the white-rot/brown-rot paradigm for wood decay fungi. *Proceedings of the National Academy of Sciences*, 111(27), pp. 9923-9928.

Sykes, R., Yung, M., Kirst, M., Peter, G. and Davis, M. (2009). High-Throughput Screening of Plant Cell-Wall Composition Using Pyrolysis Molecular Beam Mass Spectroscopy. In: J.R. Mielenz, ed., *Biofuels*. Jonathan R. Mielenz. Methods in Molecular Biology book series (MIMB, volume 581), pp. 169-183.

EFFICIENCY OF CELLULOSE SILANISATION – THE INFLUENCE OF SEASONING CONDITIONS

Authors: Joanna Siuda*, Bartłomiej Mazela, Waldemar Perdoch, Magdalena Zborowska

About the corresponding(presenting) author:



JOANNA SIUDA

WWW.WTD.UP.POZNAN.PL

JOANNA.SIUDA@UP.POZNAN.PL

MOTIVATION

Wood silanization is a process of its superficial or volumetric modification through the treatment with organosilicon compounds. The mechanism of such modification is based on covalent bonds formation between hydroxyl groups from cellulose or lignin and hydrolysed silanes. Water plays a crucial role in case of hydrolysis reaction. That's why moisture content fluctuation of the modified material is a key issue during its seasonig, which influence the efficiency of the hydrolysis reaction. The aim of the research was to compare intensity of peaks (Si-CH_3) at IR spectra of cellulose modified with MTMOS during variable humidity conditions.

EXPERIMENTAL

Silanization

Pure natural polymers were used in the study: cellulose, in the form of powder with 50 µm grain diameter. Ethanol solution of methyltrimethoxysilane (MTMOS) was used as a silanization agent. Aluminium acetylacetonate (Al(acac)$_3$) was used as a catalyst.
The silanization was carried out for 24 hours at room temperature in a magnetic stirrer. After that the mixture was centrifuged (20 min, 2500 rpm). Cellulose was separated from the solutions by decantation. Both polymers were dried in two ways: 1). drying in a laboratory dryer at 60°C for 24h; 2). drying in a desiccator (above silica gel) at room temperature.

FT-IR analysis

The IR analyses were performed after drying. FTIR spectra were obtained by means of FTIR spectrometer (Bruker Optics GmbH). The treated cellulose was dispersed in a matrix of KBr, followed by compression to form pellets.

RESULTS & DISCUSSION

Figure 1 shows spectra of cellulose silanized with MTMOS in the presence of Al(acac)$_3$ dried in two different processes: in laboratory dryer (1) and in a desiccator (above silica gel) (2). Peaks at

$1270\ cm^{-1}$ and $770\ cm^{-1}$, corresponding to $Si\text{-}CH_3$ moiety, was observed on the spectra of cellulose modified with MTMOS. Moreover, presence of signals in the range of $1530\ cm^{-1}$ to $1630\ cm^{-1}$ was observed. These peaks corresponded to the catalyst.

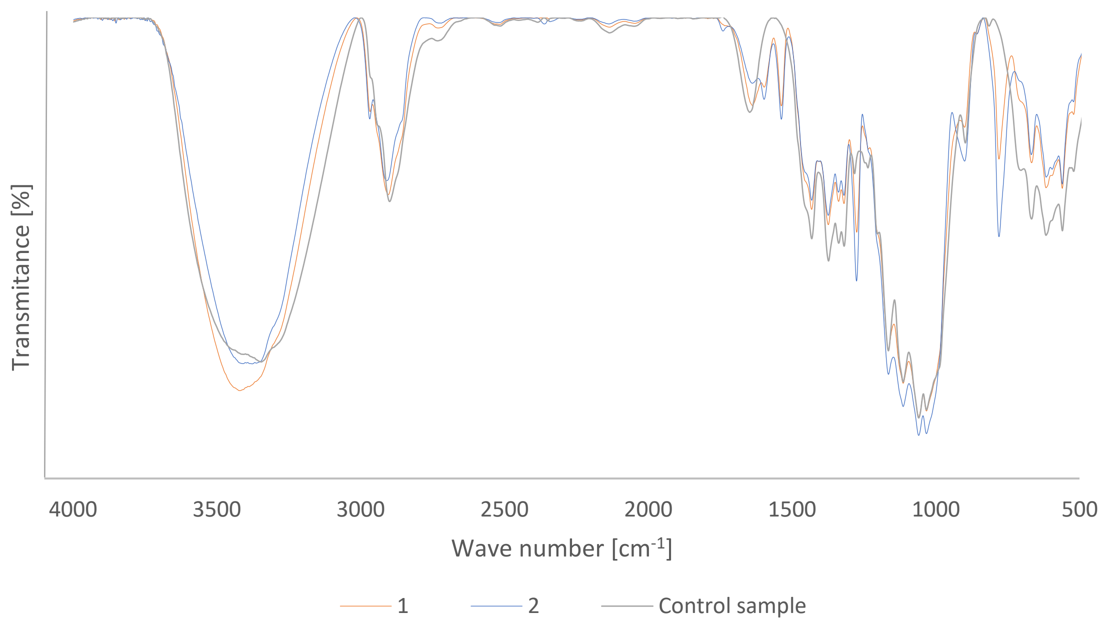


Figure 1. FT-IR spectra of cellulose silanized with MTMOS and dried in laboratory dryer (1) and desiccator (2).

The differences in intensity of the $Si\text{-}CH_3$ peaks at $1270\ cm^{-1}$ and $770\ cm^{-1}$ were observed. In case of the sample dried in a desiccator, the intensity of these peaks was higher than in the case of sample dried in a laboratory dryer. In the dryer, the humidity was limited and the MTMOS evaporated. Both made it impossible to continue the hydrolysis, as opposed to the samples in the desiccator.

CONCLUSIONS

1. Seasoning of samples had influence on silanization process. Samples seasoned at higher humidity were characterized by a higher efficiency of silanization.
2. Higher yield was obtained for the samples dried in a desiccator. It means that the efficiency of silanization increased due to higher humidity.

Acknowledgements

The research was partially supported by the Polish Ministry of Science and Higher Education as a part of the "Cultural heritage–research into innovative solutions and methods for historic wood conservation" project within the National Programme for the Development of Humanities in 2016-2019 (project No. 2bH15 0037 83).

REFERENCES

Abdelmouleh, M., Boufi, S., Salah, A., Belgacem, M., Gandini, A. (2002). Interaction of Silane Coupling Agents with Cellulose. *Langmuir,* 18*,* pp. 3203-3208.

Brinker, C. (1988). Hydrolysis and condensation of silicates: effects on structure. *Journal of Non-Crystalline Solids*, 100, pp. 31-50.

Brochier, S., Abdelmouleh, M., Boufi, S., Belgacem, M., Gandini, A. (2005). Silane adsorption onto cellulose fibers: Hydrolysis and condensation reactions. *Journal of Colloid and Interface Science*, 289, pp. 249–261.

Castellano, M., Gandini, A., Fabbri, P., Belgacem, M. (2004). Modyfication of cellulose fibers with organosilanes: Under what conditions does coupling occur? *Journal of colloid and interface science*, 273, pp. 505- 511.

Jiang, H., Zheng, Z., Wang, X. (2008). Kinetic study of methyltriethoxysilane (MTES) hydrolysis by FTIR spectroscopy under different temperature and solvents. *Vibrational Spectroscopy*, 46, pp. 1-7.

Launer, P. (1987). Infrared analysis of organosilicon compounds: spectra structure correlations. Reprinted from Silicone Compounds Register and Review. Edited by B. Arkles et al., Petrarch Systems.

Pandey, K. (1999). A Study of Chemical Structure of Soft and Hardwood and Wood Polymers by FTIR Spectroscopy. *Journal of Applied Polymer Science,* 71, pp. 1969–1975.

Tshabalala, M., Kingshott, P., Van Landingham, M., Plackett, D. (2003). Surface Chemistry and Moisture Sorption Properties of Wood Coated with Multifunctional Alkoxysilanes by Sol-Gel Process. *Journal of Applied Polymer Science*, 88, pp. 2828-2841.

Zhang, Z., Sakka, S. (1999). Hydrolysis and Polymerization of Dimethyldiethoxysilane, Methyltrimethoxysilane and Tetramethoxysilane in Presence of Aluminum Acetylacetonate. A Complex Catalyst for the Formation of Siloxanes. *Journal of Sol-Gel Science and Technology*, 16, pp. 209–220.

MECHANICAL PROPERTIES OF ACETYLATED RUBBERWOOD (*HEVEA BRASILIENSIS*) SUBSEQUENT TO ACCELERATED WEATHERING

Authors: Samuel Olaniran*, Etienne Cabane, and Markus Rüggeberg

About the corresponding (presenting) author:

SAMUEL OLANIRAN

http://www.ifb.ethz.ch/woodmaterialsscience/

OLSAMUEL@ETHZ.CH; +41764942025

MOTIVATION

The primary purpose of growing rubber tree is to produce latex for rubber and tire industries. However, its wood has become a veritable alternative timber source in Nigeria. Rubber wood has low durability and is dimensionally unstable [1,2]. Therefore, a measure of protection is required to enhance its service life. To do this, chemical modification by acetylation was chosen on the basis that it is already a commercialized method and could easily be adopted in Nigeria. Earlier reports have shown the beneficial effect of acetylation on dimensional stability and on resistance to biotic and abiotic agents [3,4,5]. Other studies also report on changes in mechanical properties of wood due to acetylation [6]. However, the long-term effect of weathering on the mechanical properties of acetylated wood has yet to be studied in detail. In this study, we show the effect of acetylation and subsequent weathering on tensile stiffness of Rubber wood.

EXPERIMENTAL

Rubber wood samples with the dimensions of 50 mm ×15 mm ×1 mm (L x T x R) were prepared and grouped into four treatment batches; reference and acetylated un-weathered, reference and acetylated weathered for two, three and four weeks. Rubber wood samples were oven-dried at 65°C for 48 hours. Afterwards, the samples were impregnated in acetic anhydride and dimethylformamide (50v/v%) for 18 hours. The mixture was thereafter heated to 70°C under reflux for 8 and 48 hours. Acetylated samples were then washed in acetone for five days and oven-dried again at 65°C for 48 hours. The weight percent gain (WPG) was calculated. Weathering of samples was done with QUV Accelerated weathering chamber (Q-Lab, Miami, USA) according to EN 927-6 standard with alternate cycles of UV and water spray. The tensile tests were carried out with a Zwick/Roell Universal Testing Machine. Elastic modulus and tensile strength were calculated.

RESULTS & DISCUSSION

Acetylation has resulted in a weight percent gain (WPG) of 6-10% at 8 and 48 hours of treatment (Figure 1). With mild treatment conditions, it apeears that the WPG attainable for rubber wood is 10% [7,8]. However, higher WPG is possible with increase in temperature and treatment time as reported in previous studies [8,9], but this may have implications for the mechanical properties. The elastic modulus of the un-weathered acetylated samples were reduced compared to the un-modified reference (Figure 2). However, the stiffness of reference samples decreased by 33% within the four-week weathering period. Weathered acetylated samples retained their stiffness, which may be attributed to the protection of cellulose against degradation. Reduction in stiffness in the weathered reference samples may be attributed to degradation of cellulose. There was no significant difference in tensile strength due to acetylation, but strength was reduced in the reference and acetylated samples due to weathering. Acetylation to low WPGs was reported to expose cellulose to higher degradation [10,11] for other species where WPG was higher than the values obtained for rubber wood in this study. It is however possible that decrease in tensile strength stems from degradation of matrix which is not protected by acetylation.

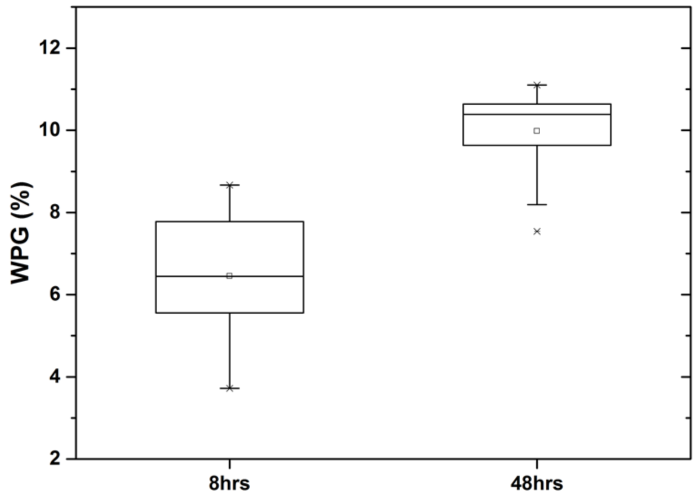


Figure 1. WPG of acetylated Rubber wood

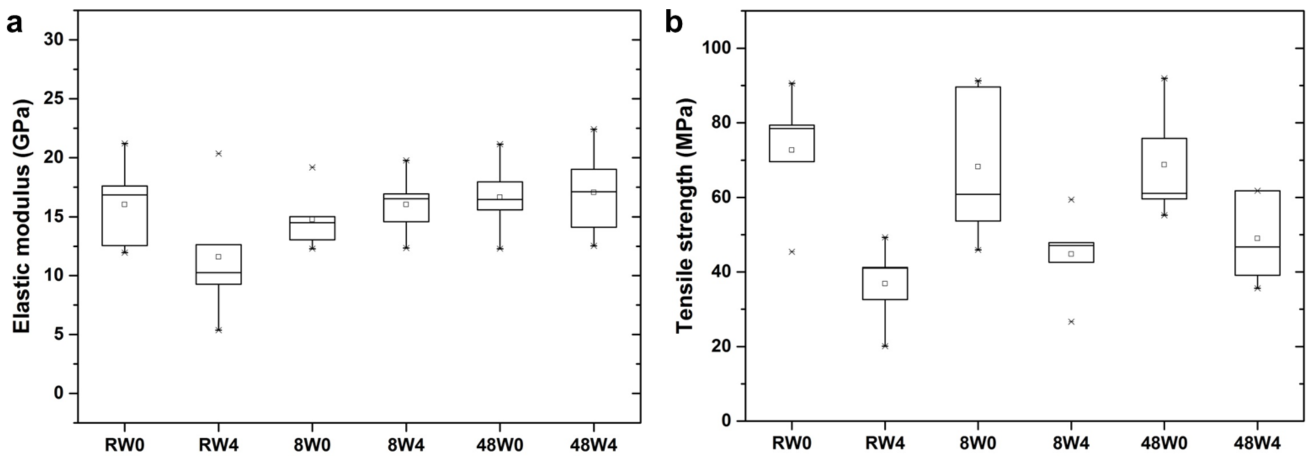


Figure 2. a) Elastic modulus and b) tensile strength of acetylated Rubber wood after weathering for four weeks (0 – not weathered; 4 – weathered for four weeks)

CONCLUSIONS

We could show that acetylation prevents a loss of stiffness of Rubber wood due to weathering. Reduction in tensile strength could have resulted from matrix degradation and washing away of lignin from the wood surface. To improve our understanding of the mechanical behaviour and the degradation of acetylated rubber wood, further analysis of the cell wall structure and chemistry is required.

REFERENCES

[1] Chauhan, S., Aggarwal, P., Karmarkal, A., and Pandey, K. (2001). Moisture adsorption behaviour of esterified rubber wood. *Holz als Roh und Werkstoff*, 59: 250 – 253.

[2] Scheffer, T.C. & Morrell, J.J. (1998) Natural Durability of Wood: A Worldwide Checklist of Species. Forestry Publications Office, Oregon State University, Corvallis

[3] Ramsden, M.J., Blake, F.S.R., and Fey, N.J. (1997). The effect of acetylation on the mechanical properties, hydrophobicity, and dimensional stability of Pinus sylvestris. *Wood Science and Technology* 31(2): 97–104.

[4] Pu, Y., Ragauskas, A.J. (2005) Structural analysis of acetylated hardwood lignins and their photoyellowing properties. *Can J Chem* 83:2132–2139.

[5] Gascón-Garrido, P., Oliver-Villanueva, J., Ibiza-Palacios, M., Militz, H., Mai, C., Adamopoulos, S. (2013). Resistance of wood modified with different technologies against Mediterranean termites (Reticulitermes spp.). *International Biodeterioration & Biodegradation*, 82:13–16.

[6] Evans, P.D., Wallis, A.F.A., and Owen, N.L. (2000). Weathering of chemically modified wood surfaces. *Wood Science and Technology*, 34: 151–165.

[7] Pandey, K.K., and Pitman, A.J. (2002). Weathering characteristics of modified rubber- wood (Hevea brasiliensis). *Journal of Applied Polymer Science,* 85(3): 622–631.

[8] Pandey, K.K., and Srinivas, K. (2015). Performance of polyurethane coatings on acetylated and benzoylated rubberwood. *European Journal of Wood and Wood Products,* 73(1): 111–120.

[9] Rafidah, K.S., Hill, C.A.S., and Ormondroyd, G.A. (2006). Dimensional stabilization of rubber wood (Hevea brasiliensis) with acetic or hexanoic anhydride. *Journal of Tropical Forest Science,* 18(4): 261–268.

[10] Evans, P.D., Wallis, A.F.A., and Owen, N.L. (2000). Weathering of chemically modified wood surfaces. *Wood Science and Technology*, 34: 151–165.

[11] Derbyshire, H., and Miller, E.R. (1981). The photodegradation of wood during solar irradiation. Part 1. Effects on the structural integrity of thin wood strips. *Holz Roh-Werkst,* 39(8): 341–350.

RESISTANCE OF PF-TREATED LVL FROM EUROPEAN BEECH (*FAGUS SYLVATIVA*) EXPOSED IN GROUND

Authors: Sascha Bicke*, Christian Brischke, Vladimirs Biziks and Holger Militz

SASCHA BICKE
WWW.HOLZ.UNI-GOETTINGEN.DE
sascha.bicke@uni-goettingen.de
+49 551 39 33561

MOTIVATION

The development of LVL from modified European beech (*Fagus sylvatica* L.) veneer aims at a utilization in load bearing constructions outdoors. In most applications, these constructions are endangered by attack of basidiomycetes, such as white and brown rot fungi. Lab tests have already proven the high durability of wood composites made from veneer, which was modified with low molecular weight phenolic resins. Due to their high mechanical strength they might be applicable also for utility poles. In soil soft rot fungi can cause strength losses of untreated wood. Against the background of a future creosote ban and an increasing copper tolerance of fungi, an alternative is wanted. The durability of LVL made from phenol-formaldehyde (PF) modified beech veneers in ground contact was validated under field conditions. Before testing full-scale poles, LVL samples from lap scale boards were tested including a variety of resins and board production parameters. Graveyard tests according to EN 252 (2015) were performed at Goettingen University and first results are presented.

EXPERIMENTAL

Specimens were taken from 139 LVL boards (50 x 50 cm²) made from phenol-formaldehyde-(PF) modified European beech (*Fagus sylvatica* L.) veneers. The combination of different Weight-Percent-Gains (WPG), densities and resin types resulted in 46 variants, each with 8-9 replicates, leading to a total number of 425 samples specimens (N=425) in the test. According to EN 252 (2015) the cross section of the specimens should measure 50 x 25 mm² (1250 mm²). Due to varying board thicknesses, it was decided to use a fixed width 25 mm, but the thickness varied between 20 and 31 mm (on average 26 mm thickness and 650 mm² cross-section). The full length of each sample was 480 mm and half of it was driven into the soil on the test field at the Faculty of Forest Sciences and Forest Ecology at the University of Goettingen. The presented results comprise the first three years of exposure and it is planned to continue the test for at least 5 years.

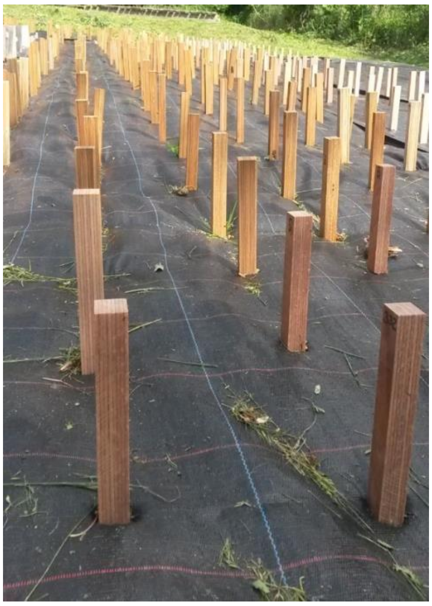


Figure 1: Test field for determining the durability of wood and wood-based products in soil contact at Goettingen University. Here: PF-modified beech LVL.

Specimens were assessed once a year and the extent of decay was graded according to EN 252 (2015) on a five-step scale as follows: (0) No attack; (1) Slight attack; (2) Moderate attack; (3) Severe attack and (4) Failure. Deviations in resulting minimum residual cross section due to varying thickness parameters of the specimens are given inTable 1.

Table 1: Modified scheme for evaluating the attack of PF-modified beech LVL.

Rating	Description	Definition	Minimum residual cross section
0	No attack	No change perceptible by the means at the disposal of the inspector in the field. If only a change of color is observed, It shall be rated 0.	100%
1	Slight attack	Perceptible changes, but very limited in their intensity and their position or distribution: changes which only reveal themselves externally by superficial degradation, softening of the wood being the most common symptom.	85%
2	Moderate attack	Clear changes: softening of the wood to a depth of at least 2 mm over a wide surface (covering at least 10 cm²) or by softening to a depth of at least 5 mm over a limited surface area (covering less than 1 square centimeter).	58%
3	Severe attack	Severe changes: marked decay in the wood to a depth of at least 3 mm over a wider surface (covering at least 25 cm²) or by softening to a depth of at least 10 mm over a more limited surface area.	36%
4	Failure	Impact failure of the stake in the field.	-

RESULTS & DISCUSSION

Specimens from untreated Beech LVL exhibited severe soft rot decay already after the first year of exposure and nearly all control specimens failed after the second year (***Figure 2***).

Figure 2: Failed controls (a) and PF-treated samples (b) after 24 months of exposure.

All PF-modified Beech LVL withstood a duration of 3 years – no failure occurred. Slight differences between decay ratings of LVL treated with different resins occurred (***Figure 3*** to ***Figure 5***) indicated that their molecular weight and alkalinity affected the durability of the LVL. The decay rate of LVL with higher compression (6 N/mm²) was lower compared to less compressed LVL (2 N/mm²), especially at a lower WPG of 15% (***Figure 3*** and ***Figure 4***). Soft rot decay in all variants with this WPG appeared to develop further.

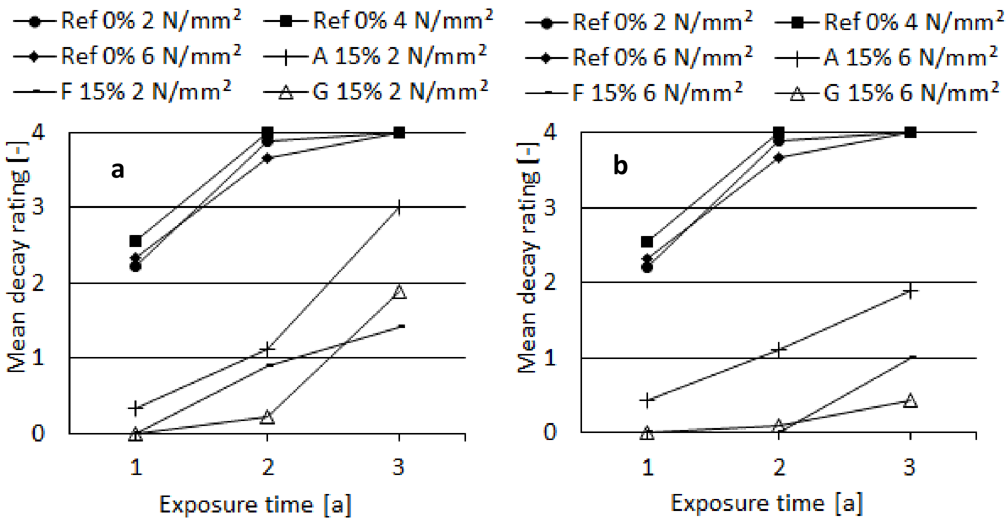


Figure 3: Mean decay rating according to EN252 (2015) of undensified (a) and densified (b) PF-treated Beech LVL modified with different PF resins (A,F,G) at a WPG of 15%.

At a WPG of 30%, the undensified variants (2 N/mm²) exhibited a slight attack (rating 1) after three years independent from the resin type. The densified variants (6 N/mm²) differed in a way that the resin type A remained unchanged with no attack, whilst resin type D and E showed a slight attack (Figure 4).

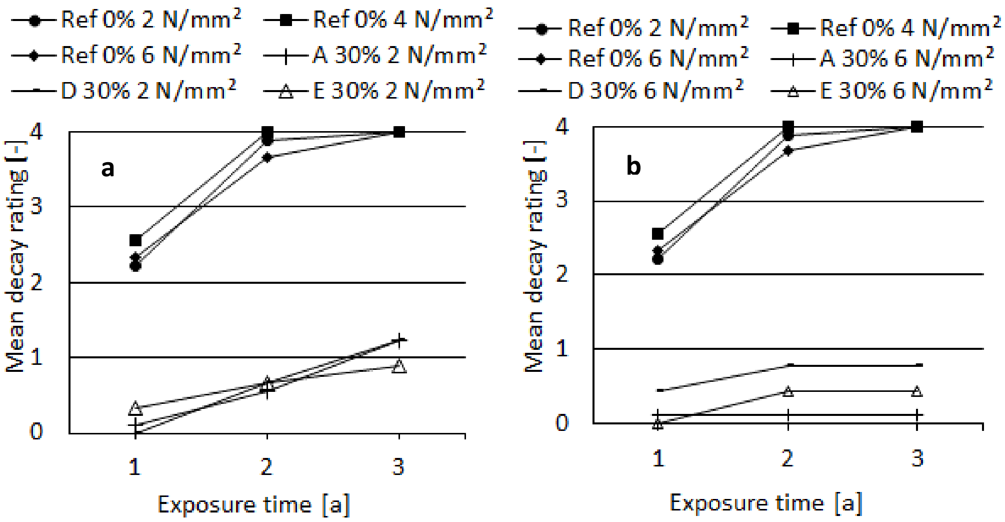


Figure 4: Mean decay rating according to EN252 (2015) of PF-treated undensified (a) and densified (b) PF-treated variants at a WPG of 30%.

The influence by WPG for a single type of resin is further illustrated in the following ***Figure 5***. Here it can be seen that the decay is also much slower for the higher WPG, as the mean rating for undensified variants after three years for 30% WPG was only half the rating of the variants with 15% WPG. As shown before, the densification reduced slowed down the decay further for 15% WPG and eliminated the decay for the higher WPG variants.

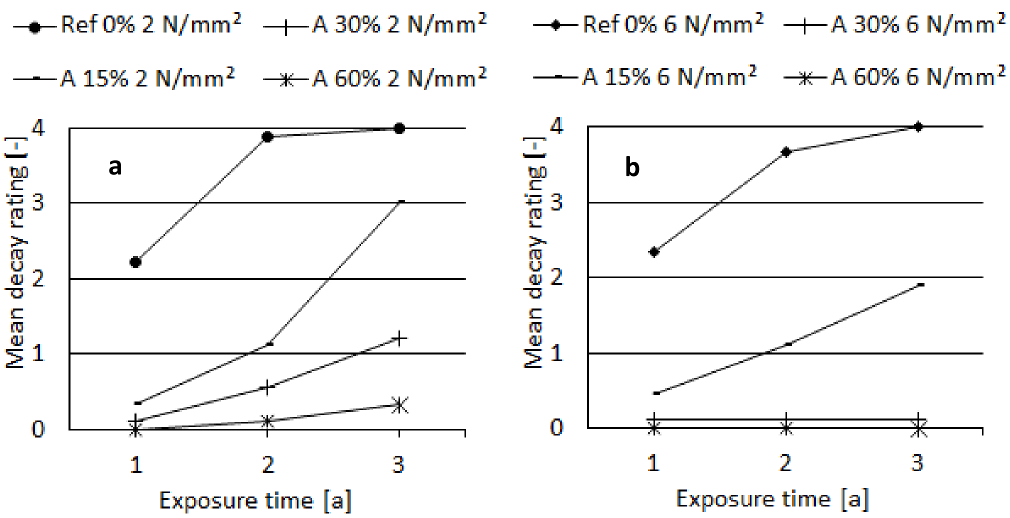


Figure 5: Mean decay rating according to EN 252 (2015) of undensified (a) and densified (b) Beech LVL treated with PF-resin type A at varying WPG.

Results from similar graveyard tests with chemically modified were recently reported by Emmerich et al. (2018). DMDHEU-treated solid wood specimens from Scots pine (*Pinus sylvestris* L.) were tested on a test field in Sweden (Stamsmåla).The Scots pine samples (1.3M and 2.1M DMDHEU) revealed average ratings of 0.5 and 0.75 respectively after three years of exposure. At a test site in Australia (Redlands), where Scots pine performed very similar, series of DMDHEU treated beech (1.3M and 2.1M) were rated between 3.3 and 0.6 after the same time of exposure. In comparison to the PF treatment, these results equal an undensified variant with 15% WPG (resin A) and a densified variant 30% WPG (resin E).

CONCLUSIONS

PF-treatment of beech LVL showed an increased resistance to soft rot when exposed in-ground on a test field in Goettingen, Germany, whereas untreated Beech LVL failed completely after two years. Variants, which featured highest WPG or compression, were preliminarily classified as 'durable', however combinations with lower loading or compression showed an increased decay rating between the second and third year of exposure.

REFERENCES

Emmerich, L., Militz, H., Brischke, C. (2018). Long-term performance of DMDHEU-treated wood exposed in ground, above ground and in the maritime environment. *The International Research Group on Wood Protection,* Section 4 – Process and properties, IRG/WP18-40825. Stockholm, Sweden.

EN 252 (2015). Field test method for determining the relative protective effectiveness of a wood preservative in ground contact.

CAN THE VTT MOULD MODEL BE USED TO PREDICT MOULD GROWTH ON WOOD CLADDINGS EXPOSED TO TRANSIENT WETTING?

Authors: Solrun Karlsen Lie*, Thomas K. Thiis, Geir I. Vestøl, Olav Høibø, Lone Ross Gobakken.

About the corresponding(presenting) author:

SOLRUN KARLSEN LIE

WWW.NMBU.NO

LINK TO VIDEO ABSTRACT

SOLRUN.LIE@NMBU.NO; +4748028567

MOTIVATION

Surface mould contributes to the grey colour of unpainted wood exposed outdoors over time [1]. When planning building facades, mould growth models could thus be used to visualize the colour development and in that way facilitate a successful design. However, existing mould growth models for wood are mainly intended for indoor conditions [e.g. 2-4]. They are based on relative humidity (RH) and temperature as climatic input-data and do not consider effects of transient wetting by liquid water. This limitation might be solved by calculating microclimatic conditions [5]. The VTT mould model [2] is commonly used, but its performance under conditions that include liquid water is not known. In this study, we use data from a laboratory test that included transient wetting [6] to validate the original VTT model [2] for Scots pine sapwood and heartwood. Different estimates of RH are tested in the model and the results are compared.

EXPERIMENTAL

Mould growth test

We exposed the wood specimens to different levels of transient wetting, RH and temperature, and evaluated the mould growth weekly for 13 weeks [6]. Moisture content (MC) was measured by weighing the specimens weekly [6] and by continuously measuring electrical resistance on the surface and 3 mm below the surface.

Use of data in the VTT model

Hourly climatic data were included in the model. Both RH derived from the MC measurements and RH in the surrounding air were tested. The MC measurements were converted to RH using the formula given by Glass et al. [7], and we also accounted for varying temperature and equilibrium MC in this conversion. For the surrounding air, RH was assumed to be 100% during the wetting period hours. The VTT mould index [2] was converted into the rating system used in the laboratory study [6] to facilitate comparison of the results.

RESULTS & DISCUSSION

For pine sapwood, using RH from the surrounding air led to underestimation of the mould rating in most climates (Figure 1). Using RH derived from the MC-measurements gave overall better fit to the experimental mould rating. For pine heartwood, the different climatic input-data gave about the same estimates (Figure 1), which corresponded fairly well to the experimental mould rating. Pine sapwood generally responds more rapidly to wetting than pine heartwood [8], and we observed that the MC of pine heartwood was generally closer equilibrium with surrounding air humidity than what the MC of pine sapwood was. Our results indicate that the original VTT mould growth model can be applied for wood exposed to transient wetting, as long as the microclimate is taken into consideration. Therefore, we suggest that future research should focus on developing accurate microclimatic surface prediction models, as proposed by Charisi et al. [9], rather than developing new specialized mould growth models that directly includes free water. However, our study is based on data derived from a laboratory experiment, and validation should be conducted under real outdoor conditions in order to determine with more certainty if existing mould growth models could be used for wood exposed unsheltered outdoors. Especially sunlight might have a major impact on the results. We study mould growth as a piece of the colour development-puzzle. Future research should aim to develop a combined model that include additional contributing factors to the colour changes of wood (e.g. photodegradation) together with the mould growth.

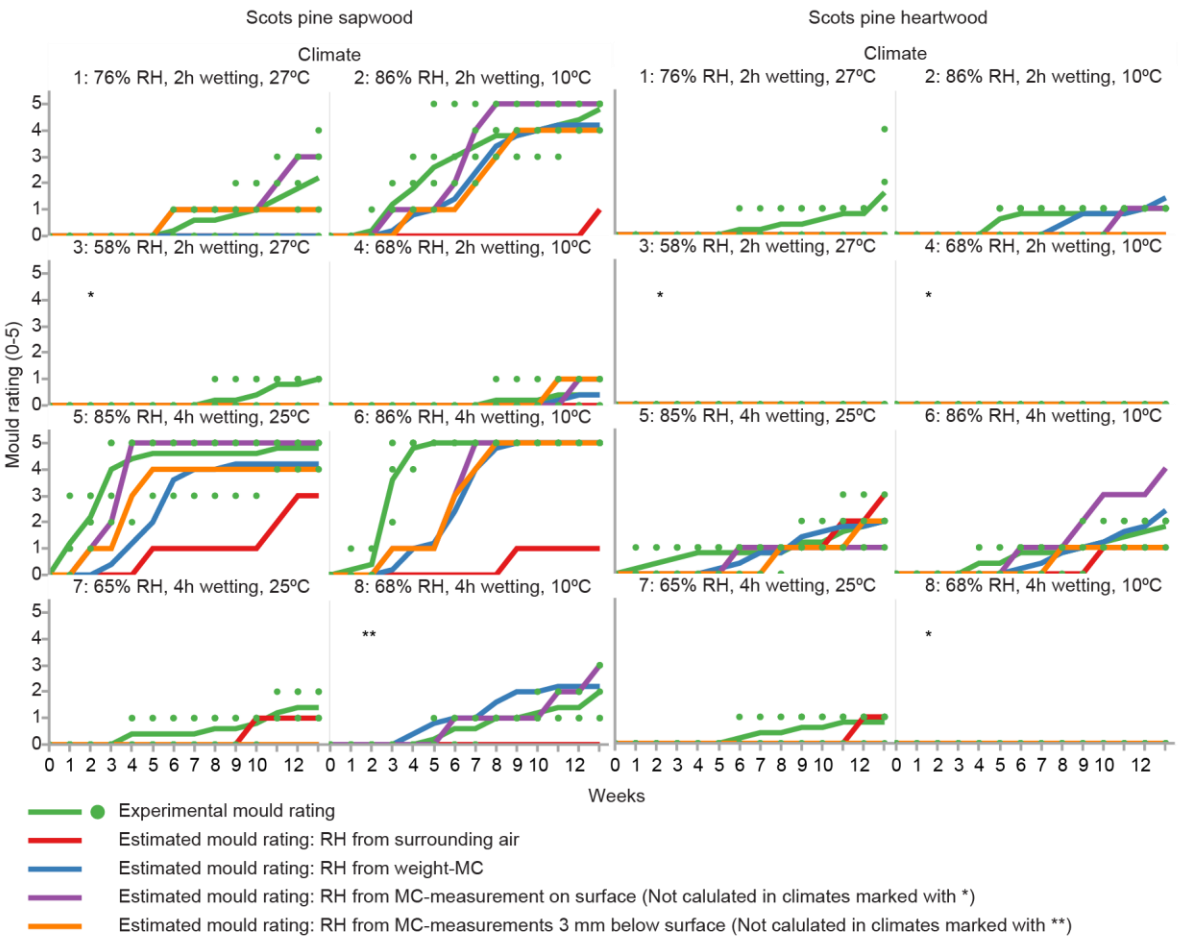


Figure 1. Experimental mould ratings from the laboratory test and estimated mould ratings derived from the VTT model. The green dots show individual mould rating of the 5 replicates, and the green line show mean values of these. For pine sapwood in climate 2 and 8, "Estimated mould rating: RH from MC-measurements on surface" are calculated from surface MC-measurements conducted on an aspen specimen.

CONCLUSIONS

Our study indicates that the original VTT mould model can be used for unpainted wood exposed to transient wetting as long as the microclimatic conditions are used as input. In the future, we will use the laboratory test data [6] to validate the model for more wood species. Further research should validate the VTT model for real outdoor conditions and further develop microclimatic moisture models.

REFERENCES

[1] Feist, W.C. and Hon, D.N.-S. (1984). Chemistry of Weathering and Protection. In: R.M. Rowell, ed., *The Chemistry of Solid Wood*, Washington, DC: American Chemical Society, pp. 401-451.

[2] Hukka, A. and Viitanen, H.A. (1999). A mathematical model of mould growth on wooden material. *Wood Science and Technology*, 33, pp. 475-485.

[3] Togerö, Å., Tengberg, C.S. and Bengtsson, B. (2011). m-model: a method to assess the risk of mould growth in wood structures with fluctuating hygrothermal conditions. *In: The proceedings of the 9th Nordic Symposium on Building Physics, NSB 2011.* Tampere: Tampere University of Technology, pp. 883-890.

[4] Thelandersson, S. and Isaksson, T. (2013). Mould resistance design (MRD) model for evaluation of risk for microbial growth under varying climate conditions. *Building and Environment*, 65, pp. 18-25.

[5] Thiis, T.K., Burud, I., Kraniotis, D. and Gobakken, L.R. (2015). The role of transient wetting on mould growth on wooden claddings. *Energy Procedia*, 78, pp. 249-254.

[6] Lie, S.K., Vestøl, G.I., Høibø, O. and Gobakken, L.R. (2018). Surface mould growth on wooden claddings – effects of transient wetting, relative humidity, temperature and material properties. *Wood Material Science & Engineering*, DOI: 10.1080/17480272.2018.1424239.

[7] Glass, S.V., Gatland II, S.D., Ueno, K. and Schumacher, C.J. (2017) Analysis of Improved Criteria for Mold Growth in ASHRAE Standard 160 by Comparison with Field observations. In: P. Mukhopadhyaya and D. Fisler, eds., *Hygrothermal Performance of Building Envelopes: Materials, Systems and Simulations, ASTM STP1599*, West Conshohocken, PA: ASTM International, pp.1-27.

[8] Brischke, C., Hesse, C., Meyer, L., Bardage, S., Jermer, J. and Isaksson, T. (2014) Moisture dynamics of wood – An approach to implement wetting ability of wood into a resistance classification concept. IRG/WP 14-20557. Stockholm: The International Research Group on Wood Protection, 14 pp.

[9] Charisi, S., Thiis, T.K., Stefansson, P. and Burud, I. (2018) Prediction model of microclimatic surface conditions on building façades. *Building and Environment,* 128, pp. 46-54.

TREATABILLITY AND INTERACTION OF VARIOUS AQUAEOUS IONIC SALT SOLUTIONS WITH EUROPEAN OAK

Authors: Tom Franke, Thomas Volkmer

TOM FRANKE
WWW.BFH.CH
TOM.FRANKE(AT)BFH.CH; +4132344143

MOTIVATION

Mineralization of wood describes the deposition of inorganic materials (e.g. P, Ca or Si) and is a process which can take under natural conditions a considerable period of time. As a result, the mineralized wood can be preserved for thousands of years [1]. There are several approaches for an artificial mineralization of wood to overcome various material drawbacks, e.g. increase the durability against wood destroying organisms or retard combustibility of wood. Various silicon based treatments where demonstrated to be suitable as fire retarders in wood [2]. Additionally, Merck [3], showed that treating wood with calcium carbonate can also improve the resistance against fire. Thus, interior applications such as parquet floorings in public buildings are a promising field of application for mineralized wood.

The aim of this study is to investigate the treatability and the interaction of European oak (*Quercus spp.*) with various ionic solution to obtain the water-insoluble salt calcium oxalate. Oak is a popular species for parquet floorings. However, processing and particularly impregnating of White oak is challenging caused by a complex and inhomogeneous wood anatomy as well as a high extractive-content. This study is intended to study a general treatability and the chemical interaction of European oak to achieve artificial mineralized oak.

EXPERIMENTAL

European oak (*Quercus spp.)* was selected as wood species. In order to precipitate calcium oxalate *in situ* in oak, two formulations were applied (Eqn 1 and 2). The aqueous solutions calcium chloride, calcium acetate and potassium oxalate were impregnated into the oak separately. Furthermore, a combination of potassium oxalate and calcium chloride, as well as potassium chloride and calcium acetate was impregnated into the oak in a two-step process, successively. Chemical changes and color changes on the surface caused by each treatment were determined by ATR-FTIR measurements. Respectively, color changes due to the treatments were measured according to the CIEL*a*b* system. Characterization of the precipitated salts, as well as their distribution in the wood were determined by SEM investigations.

$$CaCl_2 + 6H_2O + K_2C_2O_4 + H_2O \rightarrow CaC_2O_4 + 2KCl + 7H_2O \qquad (1)$$

$$Ca(CH_3COO)_2 + C_2O_4K_2 \rightarrow CaC_2O_4 + 2\,CH_3CO_2K \qquad (2)$$

RESULTS & DISCUSSION

Color changes of the treated oak are displayed in Figure 1. Treatments with alkaline potassium oxalate and acidic calcium chloride do not lead to visible color changes, whereas the alkaline calcium acetate effects a clear color change of the oak surface. However, in combination calcium chloride and potassium oxalate display color changes. A similar behavior was observed for treatment with calcium acetate in combination with potassium oxalate. For this treatment, white deposits were found on the specimen surface. ATR-FTIR investigations indicating chemical changes and degradation of lignin side-groups due to calcium chloride treatment. Furthermore, chemical changes of the oak were also observed by treatment with calcium acetate and potassium oxalate. An increasing of the peak intensity's (around 1650 cm^{-1}) might be attributed to changes in quinone content and thus a structural change of lignin and perhaps tannins is conceivable.

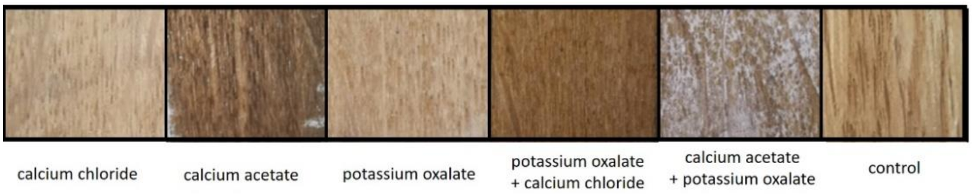


Figure 1. Color changes of the surface of European oak due to treatment with various aqueous ionic liquids

Preliminary SEM investigations display that oak is basically treatable with ionic salt solutions. An example is given in Figure 2. Various crystals with altering morphology were observed inside the cell lumina over the entire cross section, but the distribution occurred not consistent. Furthermore, the penetration and distribution inside the cell walls is unknown and shall focused in further investigations.

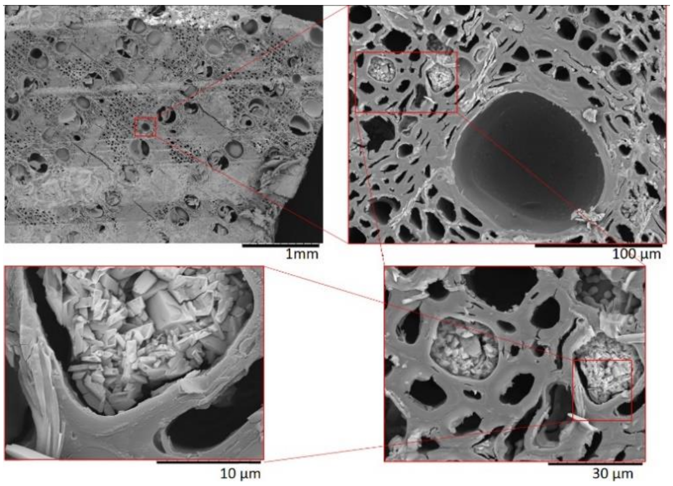


Figure 2. Deposition of precipitated salts in oak cell lumina after treatment with potassium oxalate and calcium chloride

CONCLUSIONS

Treatments with ionic solutions of calcium chlordide, potassium oxalate and calcium acetate, as well as combinations of calcium chloride / pottassium oxalate and calcium acetate / pottassium oxalate leads to chemical changes of the oak surfaces. Espeacially in combination, the treatments leading to strong color changes of the oak surface. Furthermore, deposits of crystals in the cell lumina indicating a general treatabillity of oak with ionic solutions to achieve calcium oxalate.

REFERENCES

[1] Buurman, P. (1972). Mineralization of fossil wood. Scripta Geologica 12, 1-43

[2] Mai, C., Militz, H. (2004a). Modification of wood with silicon compounds. inorganic silicon compounds and sol-gel systems. A review. Wood Science and Technology 37, 339–348

[3] Merk, V. (2016): Mineralization of wood cell walls for improved properties. Dissertation ETH Zürich, Zürich, Switzerland.

ACOUSTICAL COMPARISON OF A TMT GUITAR AND A TROPICAL WOOD GUITAR USING THE FREQUENCY RESPONSE ANALYSIS

Author: Christoph Munk*, Lothar Clauder and Alexander Pfriem

About the corresponding (presenting) author:

CHRISTOPH MUNK

WWW.HNEE.DE/MUSIKINSTRUMENTE

CHRISTOPH.MUNK@HNEE.DE

+493334657379

MOTIVATION

To this day almost all guitar makers worldwide primarily use tropical wood like palisander (*Dalbergia* spp.) for their manufacturing. Due to the current CITES regulation from January 2017 related to the trade of tropical wood it gets unavoidable to generate and establish alternative materials with equal material properties. One possibility of improvement is the thermal modification of wood which increase technical and acoustical properties of different European wood (Pfriem, 2006, Zauer et al., 2015). Besides determining material properties the sound quality of the finally build instrument is of considerable importance. Therefore the method developed at the IfM (*institute for musical-instrument making*) which enables a substantial proposition of the acoustical performance of string instruments was used to obtain an acoustical comparison of a guitar made of modified wood and a guitar traditionally made of tropical wood.

EXPERIMENTAL

Part of this study is an acoustical comparison of two guitars. One made of tropical wood [*Dalbergia nigra* (BENTH.)] and one made of thermally modified timber (TMT) [*Pyrus* (L.) and *Alnus* (MILL.)]. The test setup consists of an impact hammer (B&K Type 8204) to excite the guitar in the middle of the bridge and a microphone (PCB Model 377B02) for recording the emitted signal of the guitar body in a distance of one meter from the sound hole. On two different days 10 series of measurements (three single hammer impacts at each measurement) of both guitars were determined. To record the Data a front-end (m+p VibPilot) was used. The processing of the data was enabled by the analysis software SO Analyser 4.4 (m+p) to determine the averaged frequency response functions (FRF). The determined FRFs can be divided into several ranges which contain different acoustical information about bass, volume, clearness, brightness and sharpness of the instruments. This determining of different ranges was developed by the institute for musical-instrument making (Ziegenhals, 2016).

RESULTS & DISCUSSION

As seen in figure 1 the verification of the frequency ranges (0-5000 Hz) shows an acoustical similarity of both guitars. Slight differences are visible in the bass and volume range while the guitar made of TMT has a higher average level. More obvious differences show the range of clearness while the guitar made of tropical wood offers a higher average level. In Table 1 are listed all calculated mean sound pressure levels of the different frequency ranges for both guitars.

Table 2. Mean sound pressure level of both guitars for the different frequency ranges

mean sound pressure level L [dB]	volume L 50…5,0k	bass L 50…200	clearness L 0,8…1,2k	brightness/sharpnes s L 2,0…5,0k
TMT	-9,4	-4,2	-12,0	-16,8
Tropical	-9,6	-5,0	-10,2	-16,8

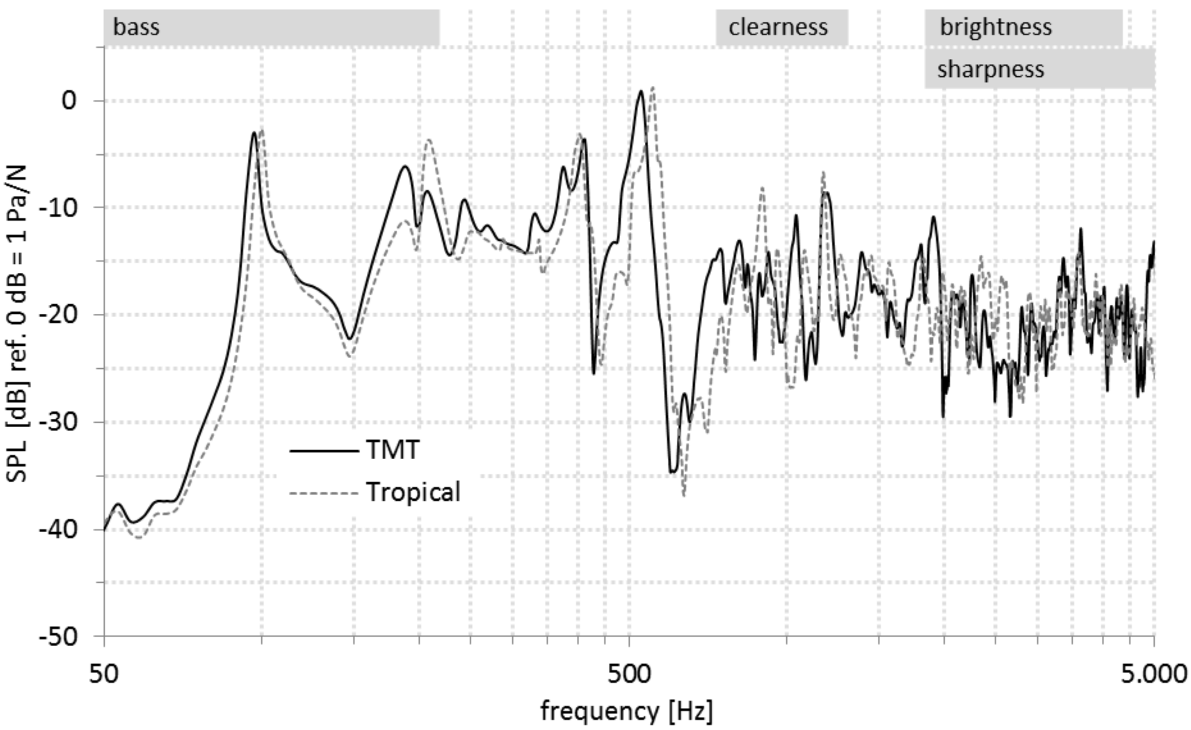


Figure 6. Frequency response functions of the TMT guitar (black line) and the tropical wood guitar (grey dotted line) in the frequency range 0-5000 Hz

CONCLUSION

In summary the method enables an efficient acoustical impression as a function of the natural frequencies of both guitars. The measured data showed similarities and therefore comparable acoustical properties. However additional effects like psycho acoustical feelings or taste in music are relevant for a complete acoustical impression of an instrument. Next to the material the acoustical characteristic of an instrument is influenced by design, construction or material processing. Therefore further empirical and fundamental research is required for a more detailed acoustical impression of an instrument like the guitar.

REFERENCES

Ziegenhals, G. (2016). Die Entwicklung der Frequenzkurvenmesstechnik im Institut für Musikinstrumentenbau. FAMA Seminar Musikalische Akustik zwischen Empirie und Theorie, Januar 2016, pp. 51-57.

Pfriem, A. (2007). Untersuchungen zum Materialverhalten thermisch modifizierter Hölzer für deren Verwendung im Musikinstrumentenbau. Dissertationsschrift am Institut für Holz- und Papiertechnik der TU Dresden. Selbstverlag TU Dresden.

Zauer, M. et al. (2015). Thermal modification of European beech at relatively mild temperatures for the use in electric bass guitars. Eur. J. wood Prod.: DOI 10.1007/s00107-015-0973-2.

AFFECTION OF EXCEED MOISTURE TO THE HYGROTHERMAL PROPERTIES OF CROSS LAMINATED TIMBER PANEL IN EXTERNAL WALL ASSEMBLIES

Author: Laura Cukkere*, Villu Kukk and Jaan Kers

About the corresponding (presenting) author:

LAURA CUKKERE

WWW.TALTECH.EE

LAURACUKKERE@GMAIL.COM;
+37129564420

MOTIVATION

This project is a part of development of overall work to be finished as Master's thesis of Technology of Wood and Plastic study program.

As Cross Laminated Timber (CLT) is comparatively new construction material in the field, and besides that, is providing very promising future possibilities in building industry, it still has to be investigated. One of the fields is the moisture affection, where the current supply of researches done is not enough. As the CLT panels are exposed to weathering – rain, snow and humidity - during both the construction and time when being installed, this may cause a serious damage not only for the panel, but also for whole wall assembly.

The main objective is to investigate CLT panel behavior in different kind of wall structures and to find a limit moisture content (MC) of CLT panel at which a possible risk of mould growth starts.

EXPERIMENTAL

In the experiment there are tested six types of wall assemblies, each containing a CLT panel, where the variable materials are insulation, gypsum board, etc. For each wall type there are used two kinds of CLT panels with different MC, therefore one type is purposely moisturized before installation. This allows to see the affection of different MC to the same wall type.

The main focus is made on moisture analysis in a wall assembly, heat conductivity and surface temperature on each layer. By collecting data from sensors installed in wall assemblies, the gained results provide a basis of analysis for certain parameters such as moisture content, relative humidity and temperature, which will affect possible mould growth.

After gaining the measured data from sensors, it is inserted in a computer simulation program Delphin, where after calibration and adjustments of material parameters can be made simulations changing the MC and finding the critical points where the moisture damage would start.

RESULTS & DISCUSSION

As the project is still a work in a progress, only one type of wall has been analyzed and adjusted in simulation program – EW 1.2_N.

Three kind of parameters - temperature, relative humidity and heat flux - were analyzed and compared from measured to calculated data. Sensor placement in the wall assemblies is shown in *Figure 1.* The comparison of one of the parameters – temperature – is shown in *Figure 2.*

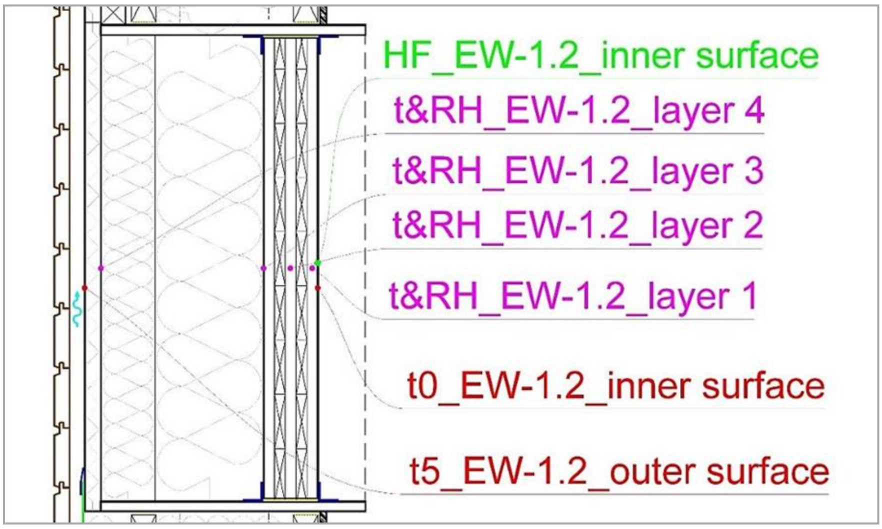


Figure 1. Sensor placement in wall EW_1.2 (Author's illustration)

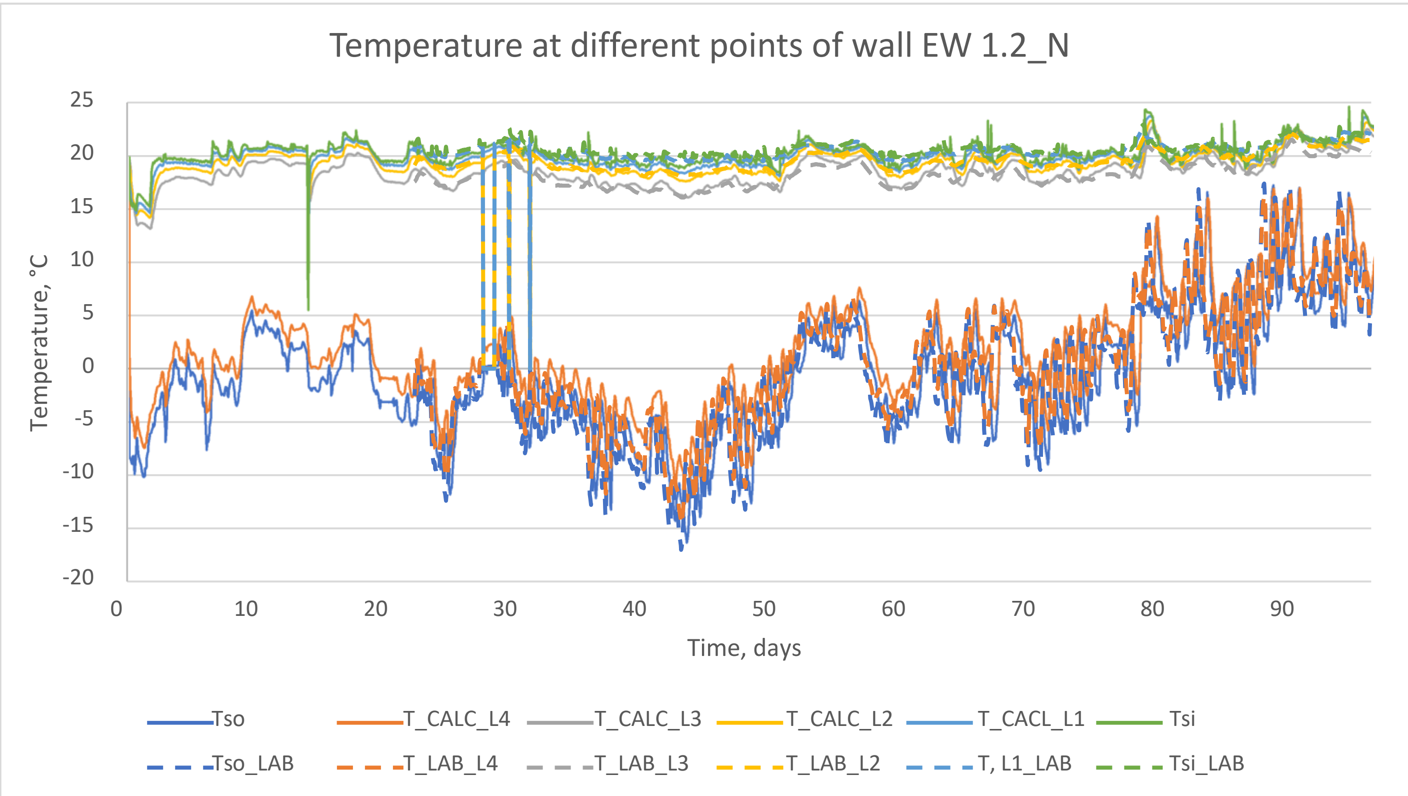


Figure 2. Temperature at different points if wall EW 1.2N. Calculated (CALC) and measured (LAB) results.

CONCLUSIONS

The initial results have showed that parameters in the simulation program still have to be adjusted, especially when it comes to relative humidity and heat flux data, which differs the most from measured results.

As the research is still in progress, there are still to be developed and adjusted simulations for the rest of wall assemblies, providing a basis for analyzing and comparing the results for different kind of wall assemblies and finding the critical conditions for mould growth.

CLT SMART - THERMAL PERFORMANCE OF MASSIVE WOOD ELEMENTS WITHOUT INSULATION

WWW.treteknisk.no

JAVAD DARVISHI

ADVISOR - BUILDING PHYSICS

MARCUS OLSSON

ADVISOR – ENERGY

jda@treteknisk.no; +47-90996270

mo@treteknisk.no; +47-46506062

The concept of massive wood element or better known as; crossed laminated timber elements (CLT) has developed to be a very robust building material in recent years. In the meantime, knowledge of the hygrothermal property of wood has been an extra motivation for the wood industry in Norway to hope to develop the product even more.

The main idea is to document that a homogeneous wood product has as good thermal properties as regular insulated timber framed wall with no further need for insulation. This means that the thermal property of wood needs to be documented better than it is today, through different national and international standards. A CLT element will close the gap between the national technical requirement (TEK 17) for thermal insulating properties for a wall (u-value: <= 0,22 W/m^{2}K , a minimum requrement) and a CLT element. In this case, the industry will have a major advantage compared to other materials such as concrete and steel. Wood or massive timber elements such as CLT has one of the lowest carbon footprints, proven to be green and enviromental friendly material which is also widely used in all buildings.

Knowledge, in the recent years, of hygrothermal effects of wood by Kraniotis and Nore, 2017 and Nore et al., 2017, shows the positive impacts of this effect on energy balance thanks to the hygrothermal property of wood, never the less, a suitable calculation method.

CLT as construction material has very good resistance to water/moisture and has no air gaps or no possibility for air circulation that might cause mold growth. On the other hand, a classic timber framed wall with insulation and gypsum interior board and exterior cladding is very much exposed to mold growth once water has entered a wall section.

Knowing the climatic robustness of the material, gives us an extra motivation to attempt to overcome an *obvious* obstacle to make CLT a competent competitor as a construction product in todays marked; the thermal insulating property. We can not relay only on the thermal conductivity of timber only at a certain temperature difference and calculate the u-value. This will not include the hygrothermal effects when heat restores and leaves wood thanks to moisture/humidity exchanges between wood and surroundings.

Figure 7 - Illustration of a flux sensor

Another question arises when we need to consider the variation of relative humidity and temperature during a certain period and include effect of moisture exchanges on the both sides of a CLT wall. Thanks to our project partner and building owner Borg Havn IKS, we have been lucky to investigate thermal conductivity of these elements on their brand-new storage/office building in southeast of Norway built in CLT wall elements. This is a large storage building built close to the harbor. In a corner of the building, we find offices where we intent to perform our experimenter a year. ***Realtime measurement of heat fluxes is one of the most realistically ways to determine U-value. Flux sensors from Hukseflux based in Netherlands has one the most reliable sensors in marked now which can be used to measure heat fluxes in the soil as well as walls and different building materials,*** Figure 7 ***and sensor type: HFP01.***

We have been monitoring the sensors and collecting data for a period of 6 months and following graph is one of the very first results we have.

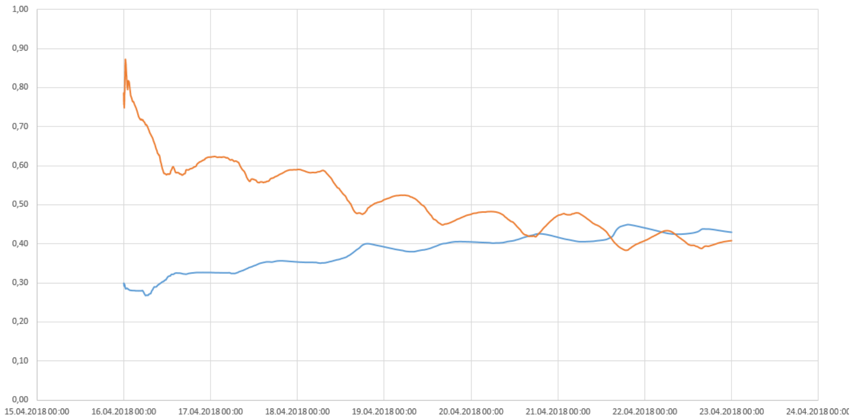


Figure 8 - Calculated U-value based on data from flux sensor for one week from north facing façade. Orange graph from sensor on outside and blue from inside.

U-value is reaching a certain limit when we have collected data for at least one week, Figure 8. It also shows the importance of calculating based on at least a 72 hours data, according to ISO standard we have chosen to follow. The daily variation is also very easy noticeable during this period; U-values tends to reach a peak during early mornings and during day decreases. It confirms the thermal heat storage in massive timber wall. This also a very common property reaction in all materials with thermal mass, such as concrete, brick and of course wood/timber.

Thanks to measuring equipment developments in the recent years, U-value can be calculated in much detail and accurate term. Monitoring indoor and outdoor conditions in additional to material behaviour according to changes in weather conditions are also very important factors.

Another aspect of importance in calculating u-value based on data from a flux sensor, is “dynamic” u-value. While we have simplified u-value in the past to be a constant, we must consider it variable. Variables such as changes in climate during different seasons, changes in air humidity and temperature in indoor environment have all influence on the thermal property (U-value) of wood and CLT elements.

However, an accumulated U-value in our experiment proves that the thermal insulation properties of wood/CLT elements are better that documented in the past and this will give an advantage to these products in wood industry in the following years.

EVALUATION OF WOOD PLASTIC COMPOSITES (WPC) OVERALY BONDING QUALITY TO THE BIRCH PLYWOOD

Authors: Karlis Kalnins*, Janis Kajaks and Juris Matvejs

About the corresponding(presenting) author:

KARLIS KALNINS

KARLIS.KALNINS@FINIERIS.LV;
+37126323411

MOTIVATION

Numerous scientists are closely related with studies of green composite materials properties. Wood plastic composites (WPC) are ones of them because WPC are perspective and widely used materials in different branches of industry [1-2]. In researches [3-6] are shown that plywood production by-products as reinforcement of polypropylene (PP), are able successfully combine. Plywood are being used a lot in construction industry with heavy loads and it's needing to be protected. Traditional paper-resin laminates are thin and easy damageable while thick plastic laminates are expensive. Our investigation focusses on WPC composite usage as overlay and adhesive activity between the birch plywood. Results show adhesion strength differences between damaged and non-damaged overlay

EXPERIMENTAL

As an overlay where used PP+45 wt.% plywood sanding dust (PSD) WPC material extruded sheets made by twin screw extruder (thickness 2 mm). As an adhesive, industry used melamine -urea-formaldehyde (MUF) glue (100g/m^2). Plywood "Riga Ply" was WGE class, thickness 12mm. Samples for investigations were prepared like described in [3, 4]. Evaluation of bonding quality experiments were done according to the European Standard EN 311:1992. In all tests 15-20 parallel samples were used. The adhesion fracture mechanisms of the samples were evaluated visually. Samples were used as shuttering system panels – each time was 72h long (concrete "SAKRET BH" hardening time).

RESULTS & DISCUSSION

Samples were prepared with different deep scratches on protective WPC (PP+45 wt.% PSD) overlay. 50-100 mikron deep damages are usually made transporting or machining plywood. It's visible but it's hard to feel it by hand. 100 – 250 mikron deep scratches are usually made during the usage process – shuttering systems for construction industry. Average resin-paper laminated plywood panel usage for shuttering systems is 7-15 times. Adhesive strength experimental results are presented in the Table 1. All these measurements show that average bonding strength between WPC (PP+45 wt.% PSD) overlay and plywood was higher than between plywood layers.

Table 1. Sample boning strength after usage.

Damage deep	Non-used N/mm^2	1 time N/mm^2	3 times N/mm^2	5 times N/mm^2	10 times N/mm^2
0 mikrons	2,79	2,70	2,77	2,72	2,66
50 mikrons	2,81	2,66	2,72	2,74	2,80
100 mikrons	2,68	2,79	2,69	2,67	2,76
150 mikrons	2,73	2,75	2,68	2,78	2,79
250 mikrons	2,67	2,80	2,74	2,69	2,71
500 mikrons	2,72	2,69	2,78	2,66	2,29

Non-used test samples showed similar bonding strength values as 1, 3, 5, and 10 times used as shuttering system samples. Only exception was 500 mikron deep damaged samples. Bonding strength is ~15-16% less compared to the other samples. These samples also were broken between WPC overlay/plywood surface. Since WPC absorb water, which may affect bonding quality, these kinds of damages are weak points but not critical, because bonding strength is more than minimum (1 N/mm^2) according to the EN 314 Plywood standard.

CONCLUSIONS

Tests showed that WPC overlay excellent possibilities of the usage as protective layer of the birch plywood. Only more than 250 mikrons deepe damages may affect adhesive bonding between WPC layer and plywood. Even if the damage is 500 mikrons deep, adhesion strength after 10 time using is only 16% less.

Acknowledgements
The authors gratefully acknowledge the financial support in accordance with the contract No. 1.2.1.1/16/A/009 between "Forest Sector Competence Centre" Ltd. and the Central Finance and Contracting Agency, concluded on 13th of October, 2016, the study is conducted by “Troja” LTD with support from the European Regional Development Fund (ERDF) within the framework of the project supervised by "Forest Sector Competence Centre".

REFERENCES

[1] Ramakrishna, M., Kumar V. and Singh Y. (2009). Recent development in natural fibres reinforced polypropylene composites. *Journal of Reinforced Plastic and Composites*, 28, pp. 1169-1189.

[2] Mijiyawa, F., Koffi, D., Kokta B. and Erchiqui F. (2015). Formulation and tensile characterization of wood-plastic composites: polypropylene reinforced by birch and aspen fibers for gear applications. *Journal of Thermoplastic Composite Materials*, 28 (12), pp. 1675-1692.

[3] Kajaks, J. and Kalnins, K. (2014). Physical mechanical properties of composites based on polypropylene and timber industry waste. *Central European Journal of Engineering*, 4 (4), pp. 385-390.

[4] Kajaks, J. and Kalnins, K. (2014). Some exploitation properties of wood plastic hybrid composites based on polypropylene and plywood production waste. *Open Eng.* 5 (1), pp. 457-464.

[5] Kajaks, J., Zagorska, A. and Mezinskis A. (2015) Some exploitation properties of wood plastic composites (WPC) based on high density polyethylene and timber industry waste. *Journal Mater. Science*, 21 (3) pp. 396-399.

[6] Kajaks, J., Kalnins, K. and Naburgs R. (2018). Wood plastic composites (WPCs) based on high density polyethylene and birch wood plywood production residues. *International Wood Products Journal*, 9 (1), pp. 15-21.

DURABILITY OF WOOD AND WOOD-BASED MATERIALS UNDER OUTDOOR CONDITIONS

Authors: Kevin Visnapuu*, Heikko Kallakas and Triinu Poltimäe

The corresponding author:

KEVIN VISNAPUU

WWW.TALTECH.EE

KEVIN.VISNAPUU@MAIL.EE

+3726202910

MOTIVATION

Many new wood based materials have been developed in recent years but they have not been tested enough in outdoor conditions. During this project 120 variously treated wood and wood-based materials are being tested. This research is done in collaboration with BIO4ever. BIO4ever is an international project where the durability of wood materials is being tested in outdoor conditions. Materials that are being tested have been received from 31 companies from 17 different countries.

The purpose of this research is to find out which wood-based materials are the most durable in outdoor conditions

EXPERIMENTAL

120 different wood and wood-based materials are being tested in outoor conditions. Experiments are conducted in 4 different locations: Tallinn (Estonia), San Michele (Italy), Oleron Island (France) and French Guyana (France). Materials have been gathered from 31 different companies worldwide.

During this experiment materials are located on the stand in a 45 degree angle so that they would be exposed to the sun and so that water could move away from the stand. The durability of materials was measured by the change of their colour, visual assessment and the apperance of cracks during the outdoor exposure. Specimens are also pictured every month to make a collage about how they changed during the exposure time. Methods for experiments have come from COST Action FP1303 instructions that have been put together by different specialists from the European research organisations and universities.

RESULTS & DISCUSSION

Short summary of the results that have been gathered after a 1 year of outdoor exposure are being presented in the following paragraphs.

The colour measurement results indicated that the most durable test-specimens are colured and varnished materials. Thermally modified and natural specimens were the worst at obtaining their colour.

By visual assessment the Kebony (chemically modified) and a pine (thermally modified + coloured with ferrous sulphate) became patchy. The bamboo coated chipboard lost its bamboo coating entirely (Figure 1). Natural specimens have lost their colour rapidly and cracks have appeared on their surface.

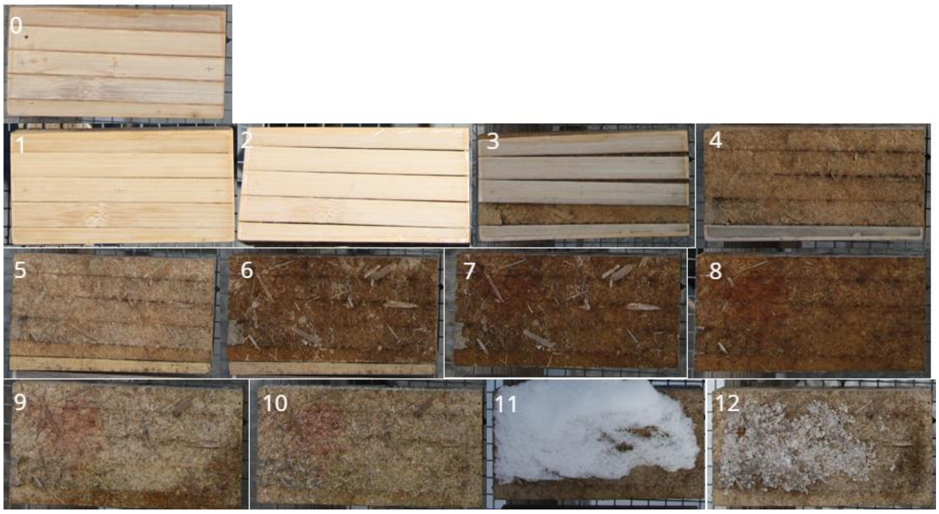


Figure 1. Change of a bamboo coated chipboard during 12 months of exposure

The cracks occured on 45 test specimens. Cracks appeared mainly on natural and somehow surprisingly on thermally modified specimens.

Outdoor exposure tests for wood-based materials are still on-going and these are only preliminary results.

CONCLUSIONS

This research is done in collaboration with BIO4ever. BIO4ever is an international project where the durability of wood materials is being tested in outdoor conditions. During this project 120 variously treated wood and wood-based materials are being tested.

The durability of materials was measured by the change of their colour, visual assessment and the apperance of cracks during the outdoor exposure. After 1 year of exposure coloured and varnished materials seemed the most durable while natural materials seemed one of the less durable materials.

Outdoor exposure tests for wood-based materials are still on-going and these are only preliminary results.

THE INFLUENCE OF CHIP QUALITY ON THE PHYSICOMECHANICAL PROPERTIES OF PARTICLEBOARDS

Mirski. R., Dziurka. D., Trociński. A.

Poznań University of Life Sciences, Department of Wood-Based Materials, 28 Wojska Polskiego Str., 60-637 Poznań

Due to the rising prices of timber and growing demand for wood-based materials the manufacturers of wood materials are forced to search for methods which will increase the efficiency of the available supply of raw materials. Shredded raw materials which are waste products of a different manufacturing technology can be used for the production of particleboards. The particleboard industry can use wood materials obtained by shredding smaller pieces of wood, which are waste products resulting from the manufacturing of other wood materials (waste from the sawmill industry) or the shredding of used wood. Unshredded material delivered to a sawmill is usually pre-shredded into woodchips and then it is cut into proper chips. Particleboard plants also acquire sawdust and chips during the processing of solid wood. 10-40% of this form of wood material is usually mixed with proper chips.

The aim of this study was to investigate the possibility to use unconventionally-shaped chips obtained by solid wood processing for the production of particleboards. Chips acquired from pinewood planks planed with a jointer-planer and from pieces of pinewood cut with a laboratory woodchip cutter were used in the study. Both types of chips were of similar bulk density, i.e. about 160 kg/m^3. The chips were used for the production of boards with densities of 450 kg/m^3 and 525 kg/m^3. The chips were glued with pMDI, where 5% of the dry weight of the adhesive was used for the dry weight of wood. Three-layer boards were manufactured, because they differed in the moisture of chips in individual layers. The share of the layers was 50% : 50%. The physicomechanical properties of the boards were evaluated according to the relevant standards. The study showed that the boards made from conventionally obtained chips were characterised by much better properties than the boards made from the chips acquired by wood planing. The mechanical properties of the former boards met the requirements of standard EN 312 for P5 boards. The properties of the latter boards did not even meet the requirements of lower types of boards described in the standard.

This study was financed by the National Centre for Research and Development, BIOSTRATEG3/344303/14/NCBR/2018.

DATA HARVESTING AND PREPARATION IN A WOOD DRYING LABORATORY

Author: Hannes Tamme

hannes.tamme@student.emu.ee

MOTIVATION

1) What is the background of your topic?

- Laboratory equipment produces a vast amount of data.
- Collecting data from instruments is an error-prone and time-consuming process.
- Data is rarely in a uniform format nor labelled or time-stamped.
- Data conversion is needed before analysis.

2) Why is the topic important?

Laboratory equipment characteristics may greatly vary, but they often need to work as one pipeline. The universal joint that connects them all is highly expensive, error-prone and time-consuming human labour. In order to improve its efficiency different automation techniques need to be applied.

3) What has been done already in the field?

A commercial attempt to partially mitigate the described problem is provided by National Instruments and called LabVIEW.

4) What knowledge is currently missing?

A degree in computer engineering is necessary to automatically collect and preprocess equipment output.

5) What does my paper have to offer to fill this gap?

My paper presents a method for collecting and preprocessing data from various laboratory equipment.

EXPERIMENTAL

Generic system components, presented in figure 1 and starting from top to bottom, are the following:

Laptop or workstation that runs orchestration, automation and data harvesting, preprocessing tools. All tools are recommended to be installed in a virtual environment. Virtualization is the preferred method to employ because it keeps the host computer clean and allows tool-set migration between currently available hardware.

Ethernet switch. If all items of equipment are on the same network then routing capabilities are not needed. It may be that the required infrastructure already exists.

Computer where lab equipment is attached. It is quite common that equipment is shipped together with some sort of preconfigured PC.

Equipment that needs to be automated. Some sort of programmable interface is needed.

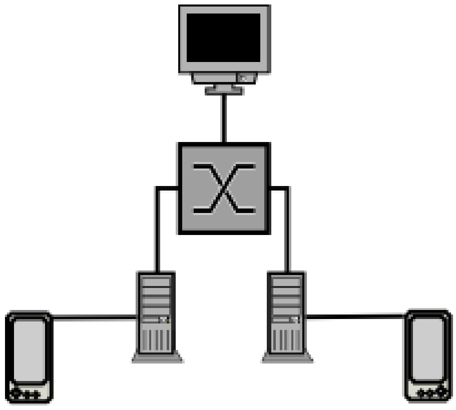


Figure 1. System architecture

RESULTS & DISCUSSION

Graphical user interface automation is done by a program named Sikuli. The communication protocol between computers is usually SSH or RDP and various subtasks are commonly fused together by common Linux utilities. The exact set up varies from day to day and lab to lab. An approach like this allows us to quickly change experiments and do self-contained documentation about what has been done. Common data harvesting use cases are given in table 1.

Table 1. Common data harvesting scenarios

Device(s)	Interface	Task	Automation solution
Resistance meter & data logger, Scantronik Gigamodule & Termofox.	Windows XP GUI, 2 x 3.5 mm audio jack	Measure and record resistance.	Connect via RDP/SSH, search GUI element point, click and type by using "Sikuli". Switch I/O channel by toggling relay connected to Raspberry Pi.
Weighing unit, Precisa.	RS232	Measure weight.	Connect via SSH, use Bash shell wrapper (minicom, grep, sed, awk etc. pipeline).
Climate chamber.	Windows XP GUI	Adjust climate chamber schedule.	Connect via RDP, search GUI element point, click and type by using "Sikuli".
Custom made hardware to measure wood charge and discharge characteristics.	Linux Bash shell	Change electrode potential. Measure/record voltage and current.	Connect via SSH, switch relays and do ADC. Record time-stamped results to removable USB storage.
AutoLab PGSTAT 30 and Spectrum GX.	Windows XP GUI	Transport data between incompatible programs.	Connect via RDP, search GUI element point, click and type by using "Sikuli" and log data.

Data preprocessing code snippet is presented in figure 2. [2] and visual data harvesting tool is shown in figure 3. [1]

```
cat /dev/ttyUSB0 | \
        stdbuf -o0 tr -dc '[\010\011\012\013\015\040-\176]' | \
        stdbuf -o0 tr -d 'V' | \
        stdbuf -o0  cut -f 1,2,3,5,6,7 -d ' ' | \
        sed -u 's/DATE/START/' | \
        while read line;do
        . . .
        echo  ${line} | tee -a /media/usb0/log.txt
        done
```

.

Figure 2. Weighting unit preprocessing pipeline.

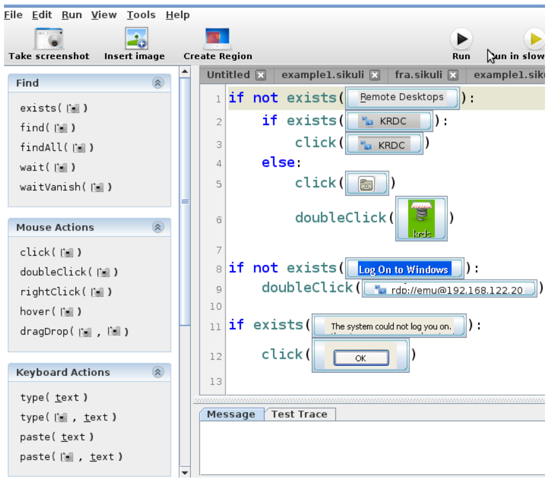


Figure 3. User interface manipulation and data harvesting tool

CONCLUSIONS

Automated data harvesting and preprocessing is a way to save time for higher-end thinking.
Repetitive tasks are something that computers can do very well.
Automated experiments are documented by default.
Data is available from one source.
Preprocessed data does not need complex manipulation before analysis.

REFERENCES

[1] Sikulix.com. (2018). RaiMan's SikuliX. [online] Available at: http://www.sikulix.com/ [Accessed 21 Jun. 2018].

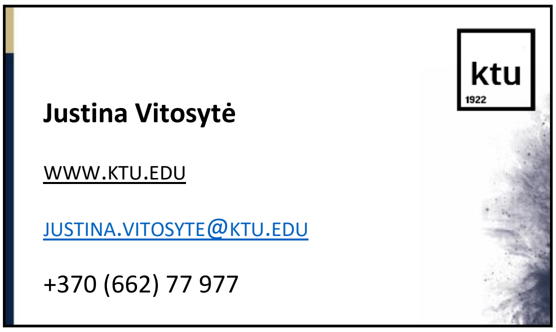
[2] En.wikipedia.org. (2018). Util-linux. [online] Available at: https://en.wikipedia.org/wiki/Util-linux [Accessed 21 Jun. 2018].

[3] Hannes, Tamme. (2013).Process management framework on the example of convective drying of wood and spectroelectrochemistry . MSc. University of Tartu, 25p.

MECHANICAL PROPERTIES OF FREE WATERBORNE WOOD COATING FILM UTILISING NANOPARTICLES

Authors: Justina Vitosytė, Kristina Ukvalbergienė

Kaunas University of Technology, Faculty of Mechanical Engineering and Design,
Department of Production Engineering, LT- 51424, Kaunas, Lithuania



MOTIVATION

The improvement of the coated wood durability can be achieved through the use of nanoscale UV absorbers in the coating systems [1]. A multiply usage of the nanoparticles or their mixtures improves the photostability and extends the decorative service life of the finished wood products [2]. Thus, a plenty of the researches, which analyses the nanocomposite wood coating by the means of decorative properties, UV-vis transmission or IR spectra data can be found. Despite that, the lack of information about the coating film mechanical properties has been highly noticed. In this research, the focus is given on the elasticity and ductility of nanocomposite coating film by means of Young's modulus and elongation at break parameters, which are commonly used to characterize the mechanical properties of the materials [3,4]. Elasticity of nanocomposite coating film is important in order to predict and to ensure its further performance onto wood surface, where the high impact of surface stress is expected and to guarantee the optimal coating interlock to wood surface as well.

EXPERIMENTAL

For the research, clear commercial waterborne acrylic dispersion was chosen with the follow technical characteristics: gloss 27 – 33 (Gardner 60°), solid content 38% (weight), specific gravity 1020 kg/m^3 ± 30 kg/m^3, viscosity 107 – 113 KU (Stromer, 23 °C). *As an additives, the different kind of dispersed nanoparticles were used (Table 1).*

Table 1. Formulations of nanocomposite wood coatings

Nanoparticles type	Particle size, nm	Acr	Acr_T	Acr_Z	Acr_H	Acr_HZ	Acr_C
TiO_2	100	—	0.5%	—	—	—	—
ZnO	20	—	—	5%	—	2.5%	—
CeO_2	10	—	—	—	—	—	5%
UVA/HALS	—	—	—	—	5%	2.5%	—

Coating film samples were prepared using a special silicon template with the thickness of 1 mm and glass plates as a background. Bone shaped sample overall length was 65 mm and widths of 13 mm and 8 mm in the clamping and stretching zones, respectively. For the each group of the nanocomposite coatings, 10 samples were prepared. Formed coatings were curried in a silicon plate under temperature of 23°C ± 2°C and a relative humidity of 50% ± 5% conditions for 24 hours. Later, silicon form was removed and samples were conditioned for 1 week. In order to remove the glass plate background, the distilled water bath was used and samples were separated using a soaking method for 1 hour. Prepared samples were additionally conditioned for 2 weeks.

Mechanical properties evaluation by means of the occurred tensile tests were performed in a universal testing machine (Tinius Olsen H10KT, USA), equipped with a 50 kN load cell. Gauge length was set to 30 mm, and pre-force of 2 N was applied. Cross-head test speed was 100 mm/min [4]. Young's modulus was calculated from the initial slope in the elastic region.

RESULTS & DISCUSSION

The results of the research are presented by means of Young's modulus of nanocomposite coatings in Fig. 1. The elongation at break values of the nanocomposite coating films are visualized in Fig. 2. High values of modulus of elasticity and elongation at break are significant in order to establish mechanical resistance of the coating film [5]. In this case, nanoparticles had a statistical impact on Young's modulus, where all types of nanoparticles (except TiO_2) increased the coating elasticity. The additives of TiO_2, despite a small amount, reduced the nanocomposite coating elasticity by 19%. The similar tendency was observed in Forsthuber et al. work [4], where 1.14% of $NTiO_2$ (particle size – 10 nm) additives decreased acrylic nanocomposite coating Young's modulus by 10%.

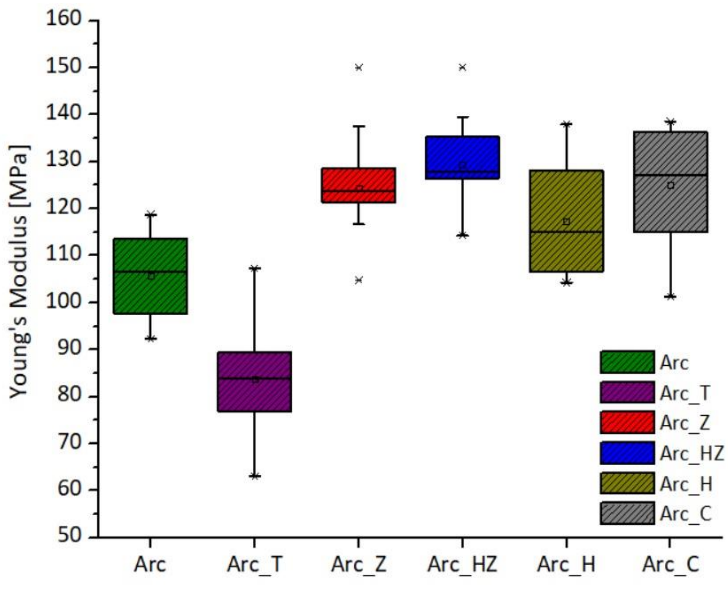


Figure 1. Nanoparticles impact on coating film elasticity

Grüneberger et al. [6] have reported, that ZnO nanoparticles additives in acrylic coatings increased the modulus of elasticity, but significant dependence of nanoparticles content (from 2.4% to 9.1%) was not observed. Nevertheless, increased elasticity was observed together with reduced elongation at break, event in small amounts of ZnO additives (0.7%).

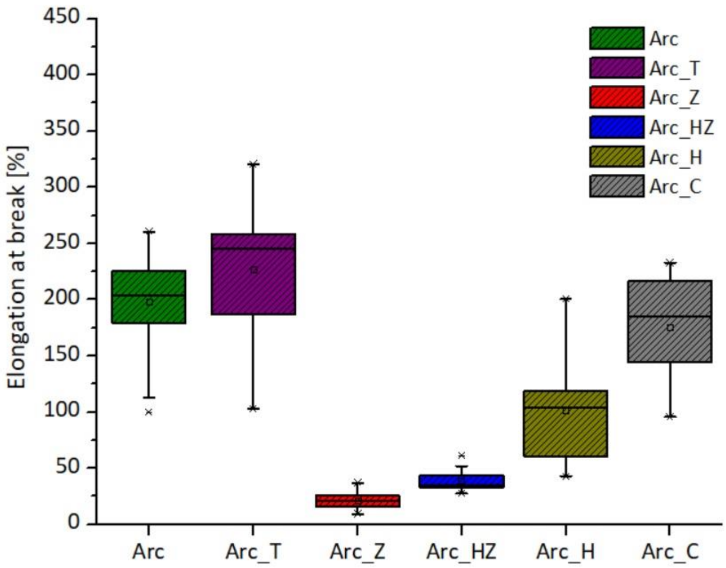


Figure 2. Nanoparticles influence on coating film extension to failure

The similar results were obtained in this research, where inorganic nanoparticles (except TiO_2) and UVA/HALS increased Young's modulus values up to 17%, but at the same time, significantly reduced elongation at break of the nanocomposite coating film.

CONCLUSIONS

Dispersed nanoparticles have an influence on mechanical properties of transparent coating film. The research confirmed, that it is necessary to evaluate the nanocomposite coating film elastic proterties and its failure in order to predict the coated wood service life, where rapid reduce of wood surface photostabilisation can be reasoned by the coating fractures. In order to clarify the impact of nanoparticles on coating film elasticity, additional experiments should be carried out, e.g. viscosity, glass transition temperature (T_g) as well as UV ageing of nanocomposite coating film.

REFERENCES

1. Miklečić, J., Turkulin, H. and Jirouš-Rajković, V. (2017). Weathering performance of surface of thermally modified wood finished with nanoparticles-modified waterborne polyacrylate coatings. *Applied Surface Science*, 408, pp. 103-109.

2. Schaler, C., Rogez, D. and Braig, A. (2012). Organic vs inorganic light stabilizers for waterborne clear coats: a fair comparison. *Journal of Coatings Technology and Research*, 9(4), pp. 433-441.

3. Tang, J., Daniels, E. S., Dimonie, V. L., Vratsanos, M. S., Klein, A. and El-Aasser, M. S. (2002). Mechanical properties of films prepared from model high-glass-transition-temperature/low-glass-transition-temperature latex blends. *Journal of Applied Polymer Science*, 86(11), pp. 788-801.

4. Forsthuber, B., Müller, U., Teischinger, A. and Grüll, G. (2013). Chemical and mechanical changes during photooxidation of an acrylic clear wood coat and its prevention using UV absorber and micronized TiO_2. *Polymer Degradation and Stability*, 98, pp. 1329-1338.

5. Overbeek, A. (2010). Polymer heterogeneity in waterborne coatings. *Journal of Coatings Technology and Research*, 7(1), pp. 1-21.

6. Grüneberger, F., Künniger, T., Huch, A., Zimmermann T. and Arnorld, M. (2015). Nanofibrillated cellulose in wood coatings: Dispersion and stabilization of ZnO as UV absorber. *Progress in Organic Coatings*, 87, pp. 112-121.

BAMBULATOR - AN EXAMPLE OF SUSTAİNABLE BİOECONOMY

Authors: Moritz Sanne*, Anja Kampe, Marcus Leonard, Nadine Herold and Alexander Pfriem

About the corresponding (presenting) author:

MORITZ SANNE

WWW.HNEE.DE/ROLLATOR

MORITZ.SANNE@HNEE.DE;

+49 3334 657384

MOTIVATION

The presented poster does not show results of an experiment or test setup. Instead, it provides a comprehensibly introduction to bioeconomy and its added value in funding proposal of any kind with a focus on lingo-celluloses-material. The importance of this topic is apparent in a climate changing world and a shift to environmentally friendly technologies. Almost every national and international funding (in Europe) requires proposals and the outcome of projects to be in accordance with the goals of national and international environmental/sustainable agreements. Even with wood technology being by definition sustainable, some researchers focus on the ecologically pillar instead of presenting a complete bioeconomical idea to the application receiver. Our "Bambulator"- project is in conformity with all sustainable pillars and covers environmental, economic, and social demands of a sustainable society. As such, it serves also as valuable example for future project proposals.

TASKS

Placing a sustainable idea

The world needs changes to be sustainable in every way. Therefore, all three pillars of sustainability (economy, environment and society) are considered in the Sustainable Development Goals (SDG) of the UN, *e.g.* in SDG 3 (*Good health and well-being*) or SDG 12 (*Responsible consumption and production)* (Biooekonomierat.de, 2018). The European Union has defined the strategy "Horizon 2020" to implement these goals in European regulations (Europa.eu, 2018). Within Horizon 2020, bioeconomy is one of the specified societal challenges. Therefore, Germany started a program to achieve the national research strategy "BioÖkonomie 2030" with funding for new products within this field. Our project was developed to the needs of customers and will present a unique and representative example of the bioeconomy to the public – the Bambulator.

Sustainable challenges/aspects

Social challenges:

Sustainability is often mistaken as only having environmental concern. One should take the benefits for e.g. customers, users, etc. into account to gain social criterions of the project. In this case, that would consider the aging society and a growing acceptance of walker customers. More than 400.000 pieces are sold each year in Germany and an increasing demand is projected with a doubling in 2030. The goals for that matter have to be a user-friendly customer-oriented distribution and maintenance system. Social changes like the demographic change (Fig.1) and the growing "Organic"-trend in the "Western" countries create innovative ideas. However, with the established bioeconomy also inversely movements were caused which lead to ignorance, alternative facts and economical short-term interests. That's why it is necessary to give an example to the people what bioeconomy can do for our society.

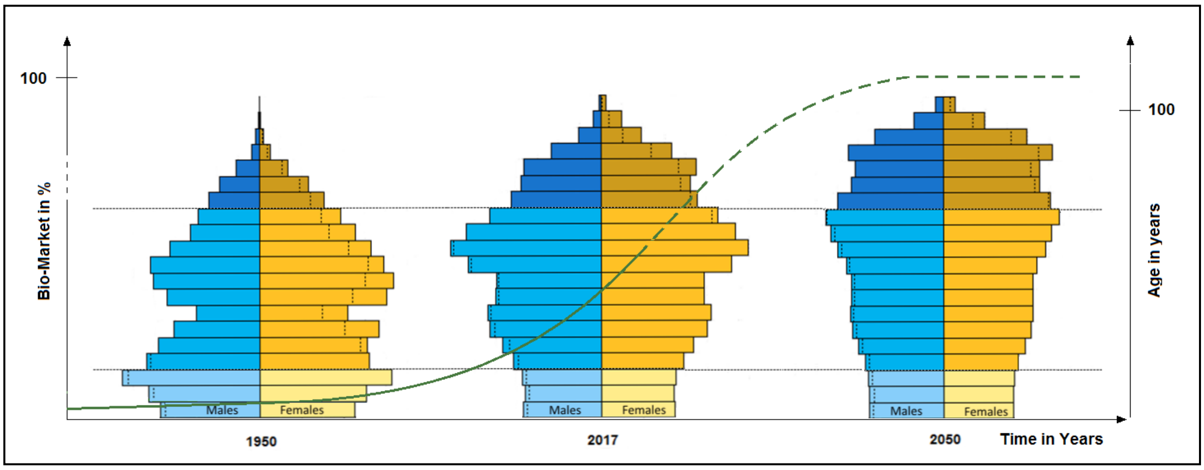


Figure 1. Stem-leave-diagram of demographic changes in global population from 1970, 2015 and predictions of 2060 (UN.org, 2018); estimated bio-market share in Europe with prediction (dashed line)

Environmental aspects:

The above challenges leads to the advantages of natural materials as one part of the environmental pillar *e.g.* Carbon dioxide bounding and almost no water pollution during the process. The Environmental Product Declaration (EPD) of a comparable aluminium walker shows significant differences to the Bambulator. At first, the acceptance of lignocellulose- based products has to be increased especially for unique products like the Bambulator by presenting advantages like its great dampening effect and the warmth of the material.

Economical aspects:

Smart and sustainable growth is a key factor and shall unify innovations. The Bambulator idea will prove that the bioeconomy is the inevitable result for a sustainable growth. Turning innovative ideas into products and processes for growth and job creation is a priority to the commission of Horizon 2020. Fortunately, green technology is raising everywhere and uses locally available materials worldwide and creates high-tech jobs. These technologies can be used in other fields as well and make the Bambulator production profitable. Even with dropping prices safety has top priority and the respective standards e.g. the CE certification have to be achieved.

Another economical advantage is shown by the numbers. The walker made in 25 years its way through Europe, but was already invented in 1978 by a Swedish polio patient. Nowadays, there are more than 400.000 walkers sold in Germany each year with an increasing demand. Furthermore, more regulations in production to hit the CO_2 reduction goal and water pollution target lead to more bio demand.

In 2016, Marcus Leonard thought of the idea to have a light weight walker made of an innovative and sustainable material like Bamboo. Considering the above sustainable pillars this project can achieve them all.

CONCLUSIONS

Everything is possible with lignocelluloses! There are many ways to fulfil the goals of the UN and therefore the EU and national strategies. In the end, the product must be sellable to the customer but be still economically producible. Our Bambulator project relies not only on the most abundant renewable material. It hits also the goals of social demand and shows in the end a best practice example of bioeconomy to the public.

REFERENCES

Biooekonomierat.de, (2018). *Biooekonomierat Germany official Website.* [online] Available at:http://biooekonomierat.de/en/bioeconomy/ [Accessed 13 Jul. 2018].

UN.org, (2018). *United Nation Official Website*.[online] Available at:https://esa.un.org/unpd/wpp/Graphs/DemographicProfiles/ [Accessed 13 Jul. 2018].

Europa.eu, (2018). *Horizon 2020 Commision Official Website*.[online] Available at: http://ec.europa.eu/programmes/horizon2020/en/h2020-section/bioeconomy/ [Accessed 13 Jul. 2018].

DENSITY AND ANNUAL RING WIDE INFLUENCE ON STRENGTH PROPERTIES OF NORWAY SPRUCE WOOD

Authors: Simonas Meškauskas*, Darius Albrektas and Inga Juodeikienė

Kaunas University of Technology, Faculty of Mechanical Engineering and Design, Department of Material Engineering* & Department of Production Engineering, LT- 51424, Kaunas, Lithuania

Simonas Meškauskas

WWW.KTU.EDU

SIMONAS.MESKAUSKAS@KTU.EDU

+370 (628) 94 864

MOTIVATION

Wood and wood products have the ability to keep a heavy loads. Due to this, it is often used in the construction industry as a reliable and ecological material. It is known, that wood strength properties depends on its density, amount and wide of the wood annual rings [1-2]. When the density of the wood is high and the width of the annual rings does not exceed the optimum limits, the mechanical properties of the wood are definitive [3]. This research object is an impact of the density and width of the annual rings on mechanical properties of lithuanian-growth spruce wood.

EXPERIMENTAL

For the study, defect free kiln-dried Norway spruce (*Picea abies* L.) wood samples with dimensions of 20×20×300 mm were chosen. In total, 400 samples were prepared, which were divided into the smaller sections (10 samples per group) according to its density and the width of the annual rings. The moisture content (MC) of the sample was determined using weighing method, where the accuracy of the electronic scales was ± 0.01 g. The initial MC of the samples varied in the range from 7.5% to 10.5% and established density was in the range from 390 kg/m^3 to 560 kg/m^3. Before the test, samples were conditioned in a climatic chamber (generating 20 ± 1 ^{o}C temperature and 60 ± 2 % relative humidity) for 15 days. The strength properties of the wood were determined using static bending method, according to ISO 13061-3:2014 [4]. For the analysis of the data, density and strength parameters were re-calculated to the normalized values (at 12% MC) respectively.

RESULTS & DISCUSSION

The strength properties dependence on the width of the annual rings of Norway spruce wood is shown in Fig. 1. The dependence of the density on the width of the annual rings is given in Fig. 2 and the density dependence on strength properties in Fig. 3.

It was found, that increasing the width of the annual rings of spruce wood, the strength properties have also slightly increased (see Fig. 1). It was determined, that the bending strength of the samples, where the width of the annual rings varied in a range from 0.3 mm to 0.4 mm, did not exceed 85 MPa. Meanwhile, when the width of the wood annual rings were higher than 0.7 mm, almost in all groups, average bending strength established a higher strength values (>80 Mpa). Earlier researches have remarked, that mechanical properties of the Norway spruce wood decrease, when the width of the annual rings exceeds the optimal values [5].

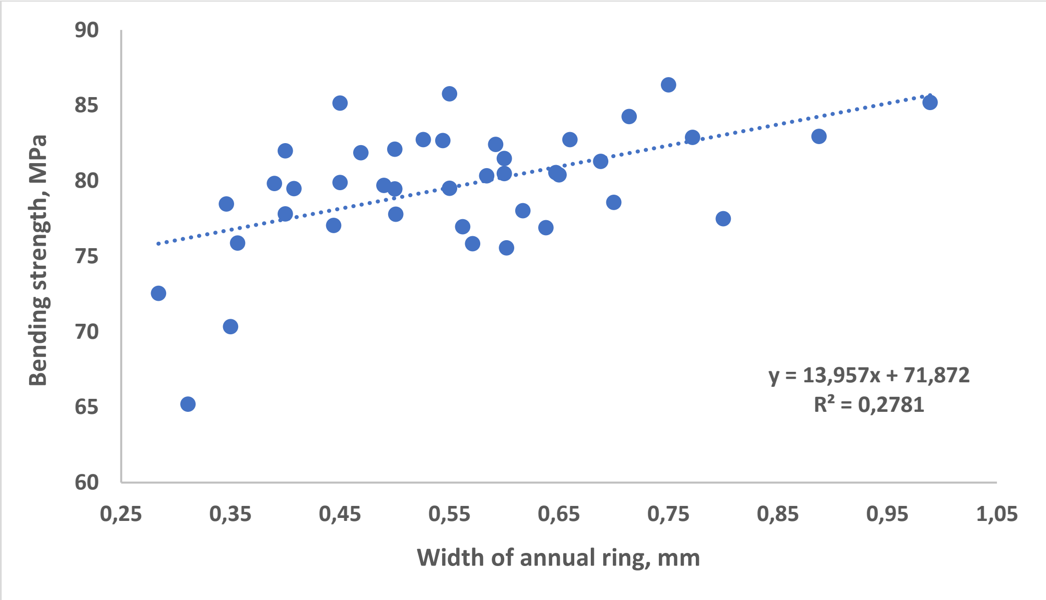


Figure 1. Influence of the width of annual rings on Norway spruce wood strength properties

Fig. 2 shows, that increasing the width of the annual rings, density of the spruce wood have also increased. When the width of the annual rings varied in a range of 0.3 – 0.5 mm, average density was 463 kg/m^3 and in the case, where the width of the annual rings was over 0.7 mm, average density was 500 kg/m^3. The dependence of the width of the annual rings and density on the spruce wood strength properties (see Fig. 1 – 2) can be explained by the increased amount of the latewood [6]. In the case, where the spruce wood density and its bending strength properties were analyzed (Fig.3), the similar correlation of the parameters was obtained. When the wood density was in a range from 450 kg/m^3 to 510 kg/m^3, the average bending strength was 80 Mpa.

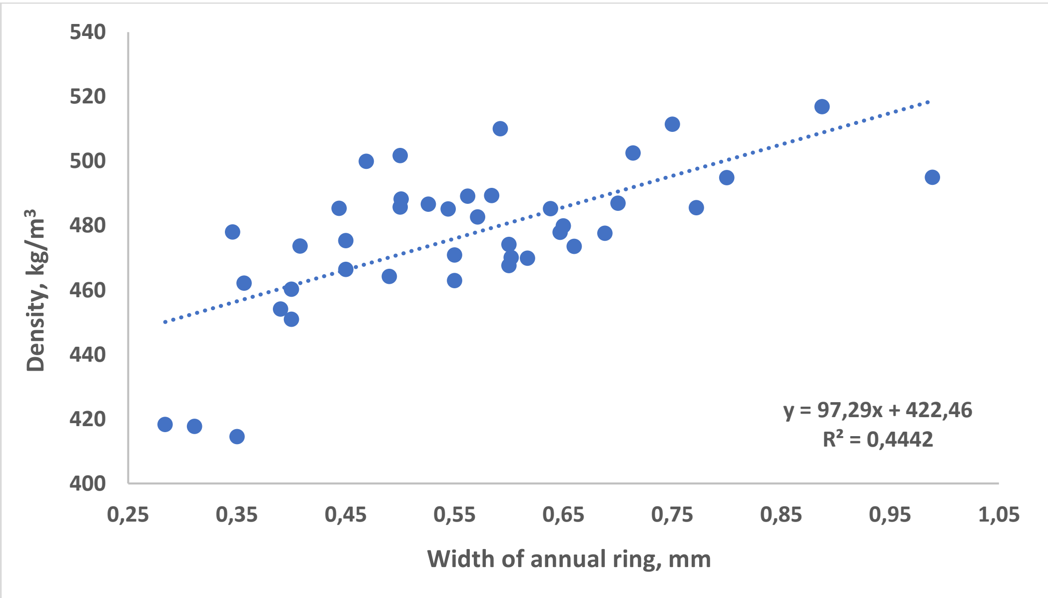


Figure 2. Influence of the width of annual rings on spruce wood density

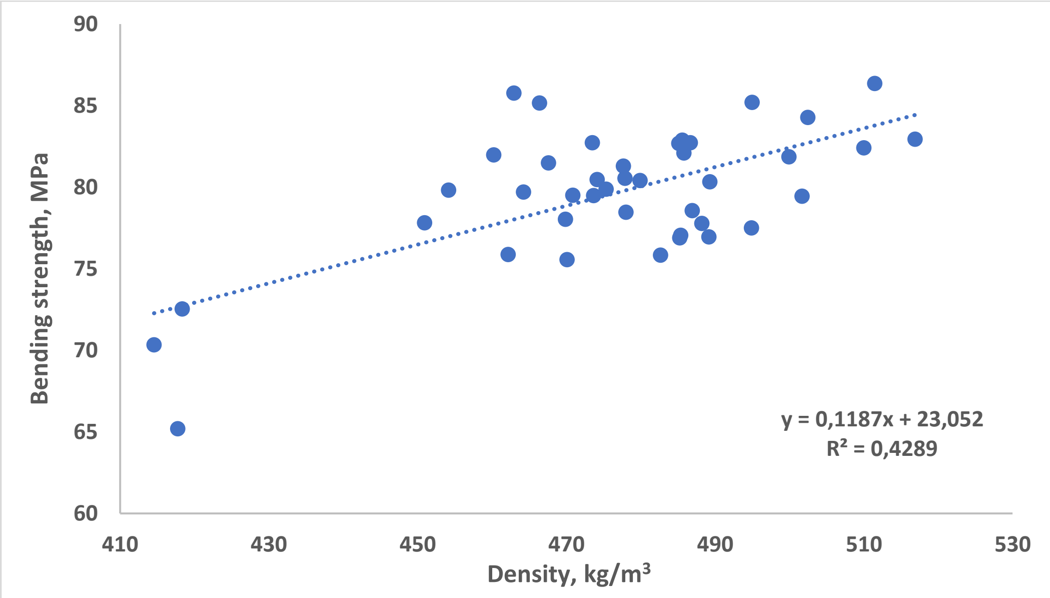


Figure 3. Norway spruce wood strength properties dependence on its density

CONCLUSIONS

The correlation between spruce wood density, width of the annual rings and bending strength was determined. Along to the width of the annual rings, average wood density increased by 24%, bending strength – 32%, as well as along to the wood density, the bending strength increased 24%. It was found, that the optimum width of the annual ring was in a range from 0.5 mm to 0.7 mm and established average density – 500 kg/m^3. Therefore, the results of this research can be applied in Lithuanian wood industry, where the mechanical properties of spruce wood are significant.

REFERENCES

1. Cardarelli,F. (2018) *Timbers and Woods. Materials Handbook*. Springer, Cham

2. Rede,V., Essert, S. and Kodvanj, J. (2017). Annual ring orientation effect on bending strength of subfossil elm wood. *Journal of Wood Science,* 63(1), pp. 31-36

3. Sopushynskyy, I., Kharyton, I., Teischinger, A., Mayevskyy, V. and Hrynyk, H. (2017). Wood density and annual growth variability of Picea abies (L.) Karst. growing in the Ukrainian Carpathians. *European Journal of Wood and Wood Products*, 75(3), pp.419-428

4. ISO 13061-3 (2014). *Physical and mechanical properties of wood. Test methods for small clear wood specimens. Part 3: Determination of ultimate strength in static bending.*

5. Lanvermann, C., Evans, R., Schmitt,U., Hering, S and Niemz, P. (2013). Distribution of structure and lignin within growth rings of Norway spruce. *Wood Science and Technology*, 47(3), pp.627-641

6. Jiang, J., Lu, J., Ren, H., Long, C. (2010). Predicting the flexural properties of Chinese fir (Cunninghamia lanceolata) plantation dimension lumber from growth ring width. Journal of Wood Science, 56(1), pp.15-18

EFFECT OF MOISUTRE AND UV RADIATION TO THE BIRCH FALSE HEARTWOOD PLASTIC COMPOSITES

Authors: Tanel Tumanov*, Marek Õunpuu, Gbenga Solomon Ayansola, Heikko Kallakas, Triinu Poltimäe, Jaan Kers

TANEL TUMANOV

WWW.TALTECH.EE

ttumanov6@gmail.com

+3726202910

MOTIVATION

The goal of this research is to study the properties of composite materials where birch false heartwood is used as filler material and suggest an economically suitable use for birch false heartwood. Wood- plastic composites (WPCs) are composite materials that combine the properties of significantly different types of materials. The idea is to form a composite from neat polypropylene (PP) and use both neat and modified birch false heartwood fibres as filler. Latter is regarded as waste in the industry and therefore is usually burned or disposed of. Therefore, it is essential to study the physical and mechanical properties of forementioned composites in order to find a possible use for false heartwood waste. Some of standardized tests have been already done in previous research and the idea is to conduct some of the same tests after immersion in water and artificial UV aging and compare the results in order to assess the effect impacted upon the physico-mechanical properties of wood-plastic composites.

EXPERIMENTAL

Different batches of WPCs are prepared including both pure birch fibre and false birch heartwood fibre for comparison. In addition some batches are subjected to modification with APTES silane binding agent which in theory should improve the binding between hydrophilic cellulose fibres and hydrophobic polymer chains. The fibre content of WPC is held at 60% by weight the remaining 40% consists of PP. Test specimens are made via injection moulding and subjected to indoor UV degradation and immersed in water for specified length of time. The UV-exposure was performed in the UV chamber with peak wavelength of 351 nm. After UV-degradation and soaking in water, standardized tests are made which include flexural, impact and tensile tests specified in ISO 178,EN ISO 179-1, ISO 527-2 etc. Comparative results are made for each batch and conclusions can be made on the endurance of each material.

RESULTS & DISCUSSION

The tensile strength before and and after UV exposure and soaking in water are shown in figure 1. Guide to abbrevations: PP- neat polypropylene; PB –pure birch filler; MP-modified pure birch filler; FHW – false heartwood unmodified; MFHW- modified false heartwood filler. The tensile strength of PP drops over 50% after exposure to UV radiation while after soaking in water does not seem to affect its strength. For WPCs the tensile strength drops after soaking in water, the UV degradation does not have a significant effect on the tensile strength.

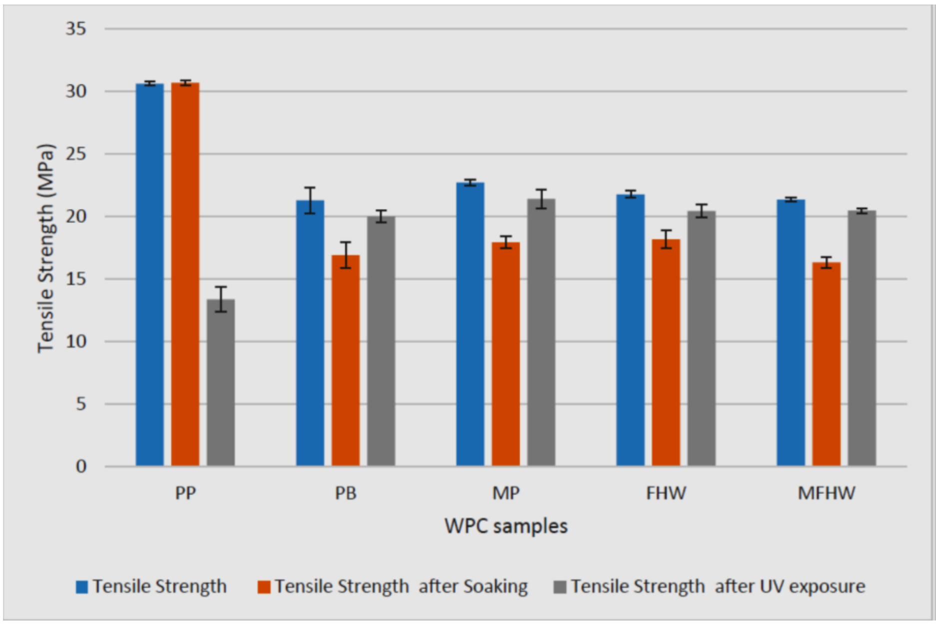


Figure 9. Tensile strength of WPC samples on exposure to UV and before and after immersion in water

The flexural strength drops in a similar way to tensile strength shown on figure 2. Again, flexural strength of neat PP drops more than 50% after UV exposure. The strength value stays the same after immersion in water for PP. WPCs all have a noticeable drop in strength after water immersion(averaging 13%) and smaller 7% drop after UV degradation.

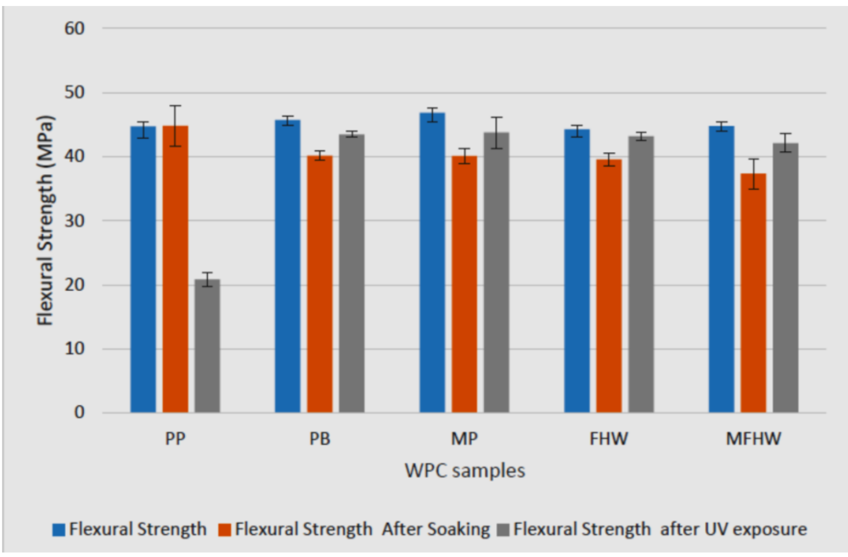


Figure 10. Flexural strength of composites before soaking, after soaking and on exposure to UV

The impact strength values drop over 80% for neat PP after exposure to UV radiation. After water immersion the impact strength of PP drops slightly. WPC impact strength values plummet by more than 70% for both water-immersed and UV-degraded specimens with no significant variance.

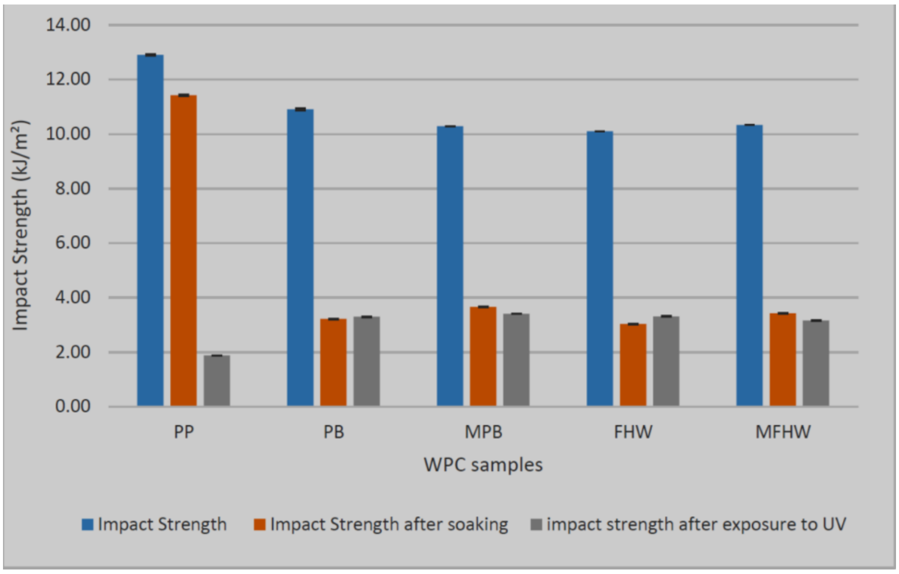


Figure 11. Influence of water absorption and UV on the impact strength of WPC

CONCLUSIONS

Both water immersion and UV exposure had a detrimental effect on WPCs strength values. Water uptake seems to have somewhat bigger effect on flexural and tensile strength than exposure to UV radiation. For impact strength, the soaking and UV exposure have roughly the same effect and impact strength decreases by approximately 70%. In addition, no significant differences between WPCs that contain pure fibres and false heartwood fibres were noticed. Also there seems to be no differences between modified and unmodified filler materials used in WPCs. Although all the strength values decreased, the flexural strength and tensile strength of WPCs were less affected by UV radiation compared to pure PP.

FREQUENCY-RESPONSE-DETERMINATION OF TONEWOOD AS AN ALTERNATIVE TO MODAL ANALYSIS

Author: Tobias Bender*, Lothar Clauder, Robert Krüger and Alexander Pfriem

Tobias Bender
WWW.HNEE.DE/MUSIKINSTRUMENTE
University for Sustainable Development Eberswalde (HNEE)
Tobias.Bender@hnee.de; +493334 657379

MOTIVATION

For instruments like Guitars or Violins, special tonewoods are required to achieve the desired sound. In order to determine the acoustic properties of such tonewoods, instrument makers and merchants of tonewood rely on procedures that require a lot of experience in the field of psychoacoustics. But none of those procedures tends to collecting data for the comparison of different types of wood (Ziegenhals, 2008).
Modal Analysis is being used to determine the vibration frequencies, mode shapes and damping for the analysis of structural dynamics of a variety of supporting structures (Ewins, 2000). This method can also be used to examine the acoustic properties of tonewood, though it requires a lot of accuracy and susceptibility in order to obtain significant data.
This study examines the possibility for an automation of this method by using a vibration calibrating system to identify the frequency response of wood samples and comparing them to the data which has been collected through modal analysis.

EXPERIMENTAL

Samples

The samples consisted of three types of wood. Ebony (*diospyros crassiflora L.*), beech (*fagus sylvatica L.*)and cherry (*cerasus ligno L.*), for three different density classes. For each type of wood, five samples with the dimensions of 190 x 28 x 6,5 mm³ (l x r x t) have been prepared.

Modal Analysis

The modal analysis was done, using an impact hammer (Brüel & Kjær, Miniature Impact Hammer IEPE Type 8204)for the impulse signal and an accelerometer (Metra, KS91C) to measure the response of the sample. The samples were stimulated on five impact points alongside the central axes of the sample, to determine the first three bending modes. The collected data was evaluated with a signal analyzer software (m+p International, SO Analyzer version 4.4.

Measurements with the vibration calibrating system

In contrary to the modal analysis, the samples are not able to swing freely during the measurement, but are mounted in a fixed state on top of the vibration calibration system (Metra, VC 110).The same accelerometer was used as for the modal analysis. The evaluation of the measurements was done by the software provided by the Metra (VC1xxCDB). A frequency sweep between 70 Hz and 4000 Hz was used to determine the frequency response of the samples.

RESULTS & DISCUSSION

As shown in figure 1, the frequency response function (FRF) determined through modal analysis is not equal to the one measured with the VC110. While the FRF of the modal analysis shows three significant peaks at the frequencies of the first three bending modes, the FRF from the measurements with the VC110 shows two double peaks and a gap in between. This is due to the fixed mounting of the Samples on top of the device. Both ends of the sample vibrate in two different frequencies, hence the double peaks. The peak for the second mode is missing, because the sample is fixed at the nodal point of this mode. The fixed mounting also alternates the frequencies of the modes by pitching them higher.

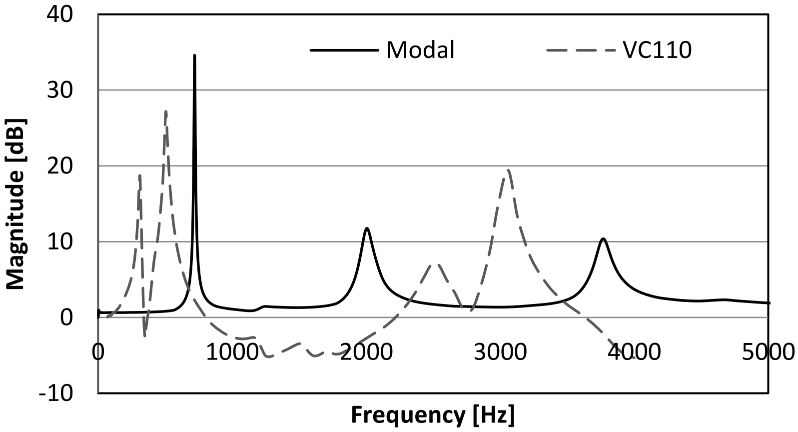


Figure 12: Average FRF of modal analysis and FRF measured with the VC110 of an exemplary beech sample.

Table 1 shows that the phase shift of the FRF which is due to the fixed mounting is always happening at a ratio of 0.7, with a relatively low standard deviation of 0.02. Therefore it is possible to transform the data measured with the VC110. The measured values concerning the damping however, have a relatively high deviation. Therefore this method is not suitable for determining the damping of tone woods at this point.

Table 3: Comparison of frequenzy an damping of the first mode for each sample, measured with both methods.

		1. Mode [Hz]			Damping [%]		
		Modal	VC110	Ratio	Modal	VC110	Deviation
Ebony	1	739,3	499,5	0,68	1,11	1,40	0,29
(*diospyros*	2	505,3	355,5	0,70	0,96	3,41	2,45
crassiflora L.)	3	790,7	539,5	0,68	1,10	2,40	1,30
	4	785,3	523,5	0,67	1,23	8,70	7,47
	5	675,9	473,0	0,70	0,85	4,03	3,18
Beech	1	735,9	507,0	0,69	0,74	7,44	6,70
(*fagus*	2	720,7	503,5	0,70	0,74	3,56	2,82
sylvatica L.)	3	789,8	549,0	0,70	0,93	3,30	2,37
	4	721,2	494,5	0,69	0,84	8,35	7,51
	5	755,7	536,0	0,71	1,16	4,29	3,13
Cherry	1	775,0	561,5	0,72	1,15	6,64	5,49
(*cerasus*	2	752,8	554,0	0,74	1,20	6,64	5,44
ligno L.)	3	762,8	551,5	0,72	0,89	5,06	4,17
	4	747,1	540,5	0,72	1,46	1,28	0,18
	5	729,4	510,5	0,70	0,86	0,59	0,27
Mean:				0,70			3,52
Standard-Deviation:				0,02			2,53

CONCLUSIONS

The results of this study show, that it is possible to determine the frequency response of tonewoods with an automated process. However the method tested in this study needs to be improved in order to generate significant data for the comparison of the acoustic properties of tonewoods. Especially the data concerning the damping shows, that this method still has its flaws.

REFERENCES

Ewins, D. (2000). *Modal Testing: Theory, Practice and Application.* Second Edition. Herdforshire: England

Ziegenhals G. (2008). *Analyse von Musikinstrumentenschallen mittels psychoakustischem Merkmalssatz (Analysis of music instrument sound waves using a set of psychoacoustic attributes).* Dresden: DAGA

WOOD SCİENCE RESEARCH İN THE NORTHWESTERN FEDERAL DISTRICT OF RUSSİA

Margarita Kisternaya*, Valery Kozlov

About the corresponding (presenting)author

MARGARITA KISTERNAYA

WWW.KIZHI.KARELIA.RU

kizhana22@gmail.com

+7 921 2212072

MOTIVATION

The main goal of the report is to introduce the conference participants to research in the field of wood science, which are held in Russia. Despite the fact that nowadays many papers are published in English, most of them are published only in Russian, in journals not included in the world citation databases and, therefore, they remain unknown to a wide range of researchers.

The review of all the research carried out in such a large country as Russia is a quite complex task. The task becomes more difficult if anyone takes into account a wide range of topics covered by wood science and engineering. Therefore, in our report we confine ourselves to the studies conducted in 2016-2018 in the Northwestern Federal District.

MAİN RESEARCH CENTRES

Northwestern Federal District is one of the eight federal districts of Russia. It consists of the northern part of European Russia. Its population is 13,616,057 (83.5% urban) according to the 2010 Census, living in an area of 1,687,000 square kilometers (651,000 sq mi).

The district comprises the Northern, Northwestern and Kaliningrad economic regions and eleven federal subjects (Fig. 1). More than 50% of the territory is covered with forests. The Region is situated on the territory of 5 forest zones. The timber stock is 10093 mln cub. m (Priroda Rossii, 2018). Main tree species are pine, spruce, birch and aspen. Different climate conditions require different approaches to forest management, and consequently forest research is needed. The main forestry research centers are situated in the big cities like St. Petersburg, Petrozavodsk (the capital of the Republic of Karelia), Syktyvkar (the capital of the Republic of Komi), Vologda (the center of Vologda region) and Archangelsk (the center of the Archangelsk region).

The research centers in Petrozavodsk and Syktyvkar are the branches of the Russian Academy of Sciences. The Forestry Technical Academy in Saint Petersburg , Northern (Arctic) Federal University in Archangelsk as well as the State Milk Academy named after N. V. Vereschagin in Vologda are under the charge of the Russian Ministry of Education and Science. The Northern Research Institute Of Forestry in Archangelsk and the Saint-Petersburg Research Institute of Forestry are under the charge of the Federal Forest Agency.

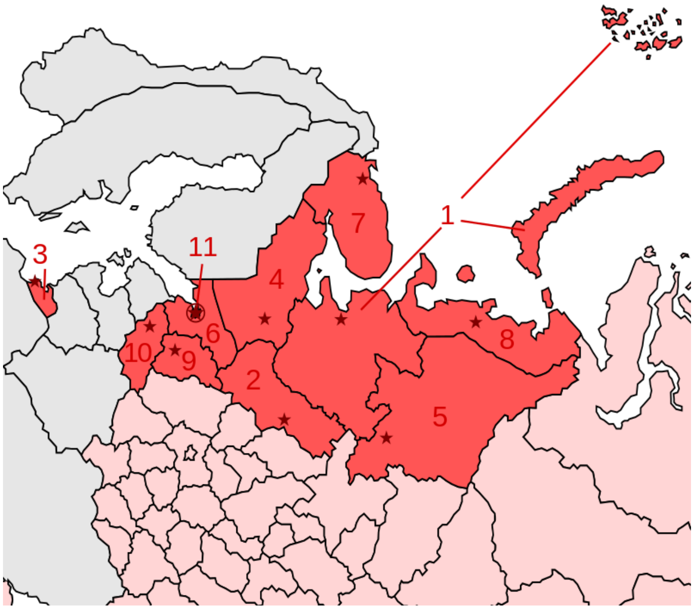


Figure 1. Northwestern Federal District: 1 - Arkhangelsk region (capital – Arkhangelsk), 2- Vologda region (Vologda), 3 – Kaliningrad region (Kaliningrad), 4 – Republic of Karelia (Petrozavodsk), 5- Komi Republic (Syktyvkar), 6 - Leningrad region, 7 – Murmansk region (Murmansk), 8 - Nenets Autonomous district (Naryan-Mar), 9 - Novgorod region (Veliky Novgorod), 10 - Pskov region (Pskov), 11 - Saint Petersburg

The research topics in forestry include complex productivity and ecological profitability of forests, development of reforestation technologies, selection, forest management, methodological aspects of economical evaluation of forests; forest seed production; standards of forest tapping,; forest estimation standards etc. The review of wood science research is given below. The review is based on the Annual Reports made by the research institutes, publications of the wood-scientists included in the National list of experts in wood science and engineering.

WOOD SCIENCE RESEARCH

Forest Research Institute, Karelian Research Centre of Russian Academy of Sciences.

The results of long-term investigation of normal and patterned wood formation were accumulated in the monograph "Structural abnormalities of woody plant stems" (Korovin, Nezvitskaya, 2017). The most frequent morphological changes in the structure of trunks and branches of woody plants are considered. When possible, explanations of these changes and the reasons for their occurrence are given. The classification of the anomalies in the structure of the stems of woody plants and the general patterns of their occurrence are presented.

The same group of researchers has published a few papers concerning the effect of sucrose exposure on the xylem anatomy of three temperate species (Tarelkina et. al, 2018) and membrane lipid composition upon normal and patterned wood formation in *Betula pendula* Roth (Novitskaya et. al., 2018). The greatest density of parenchyma inclusions in Karelian birch wood occurs at confluences of phloem flows was also reported (Novitskaya et.al., 2016).

The bacterial decay of pine wood was studied within a framework of the project "Peculiarities of wood degradation in waterlogged conditions" supported with the Russian Foundation for Basic Research (Grant # 15-08-01893) (Kozlov, Kisternaya, 2015). The bacterial decay velocity for pine was estimated and the results proved the idea that water movement in the waterlogged structures is a key factor that stimulates bacterial wood degradation.

The impact of fertilizes on the wood quality was also studied for pine seedlings growing on mineral soils (Neronova, 2017; Pekkoev et. al., 2017) and drained peat lands (Kozlov, Neronova, 2017) in forests after a fire (Sokolov et.al., 2018).

The Forestry Technical Academy

The results of the investigation of physical and mechanical properties of *Paulównia* wood and wood-destroying fungi in old building were reported on the Annual conference by the researchers of the department of wood science (Report, 2017). The same department also investigates MOE of *Prúnus pádus*, by non-destructive methods, variability of wood quality in the stem of *Álnus incána* and influence of growing condition on the structure and properties of pine wood *(Report, 2016).* Technologies in wood-fiber production are discussed in the annual conferences also (Report, 2016).

The State Milk Academy named after N. V. Vereschagin

The attempt to find the relationship between forest-growing conditions and the parameters of the knotty of the trunks was made in the Academy (Avdeev, Popov, 2017). An assessment of the knottyness of tree trunks was carried out in the Middle-aged cultures of Scots pine (55-65 years) of different forest types (southern subzone of the taiga, Vologda region). The identification of the relationship between the taxation diameter of the trunk and the maximum diameter of the knots will make it possible in future to calculate the diameters at the base of the branches according to the data of the census in the plantation, and, therefore, will simplify the work on determining the grade of timber.

Northern (Archtic) Federal University

The characteristic morphological features, ultra-microstructure, and submolecular structure of coniferous wood matrix using junipers as the representative tree were studied. The investigations confirm the physicochemical nature of the structure and self-assembly of wood substance and endorse its application in plant species. These data confirm the possibility of considering the wood substance as a nanobiocomposite. The cellulose nanofibrils (20–50 nm) and globular-shaped lignin–carbohydrate structures (diameter of 5–60 nm) form the base of such a nanobiocomposite (Bogolitsyn et.al., 2015)

The steam explosion as a method of directed influence upon the lignin–carbohydrate complex was investigated. Thermochemical activation of lignin–carbohydrate plant matrix occurs due to the directed destruction of ester and H-bonds in the lignin–carbohydrate complex, disturbance of thermodynamic equilibrium in the system and increase of mobility of labile complexes of biopolymers. T was determined that such a directed influence allows the opening of deep layers of the cell wall and provides new data about the specific composition and structure of a wood substance and its components (Bogolitsyn et.al., 2016).

Supercritical fluid extraction with carbon dioxide was shown to be a useful method for selective treatment of the weak H-bonds of the lignocarbohydrate complex to obtain new data on the structure and composition of the wood substance and its components (Bogolitsyn et.al., 2017).

The thermal decomposition of wood biofuels was studied by the researchers of the University and kinetic characteristics of the process on the basis of thermogravimetric data were determined. Biofuels were collected in the Arkhangelsk region (Marjandyshev et. al., 2015). Kinetic analysis was conducted in the framework of thermal decomposition of holocellulose of biofuels using the thermogravimetric data based on the Friedman and Ozawa-Flynn-Wall models. The results of the studies should be used in the calculation of processes and systems of thermal treating, energy-technological fuel reprocessing or multifuel burning.

CONCLUSIONS

The search and comparative analysis of publications on wood science showed that in one of the leading forest regions of Russia these studies are rather scattered. The main topics of the study are the anatomical characteristics of wood under various conditions of growing pine and spruce cultures, the problems of destruction by wood-destroying fungi and bacteria.

REFERENCES

Avdeev Yu. M., Popov Yu. P., 2017. Авдеев Ю. М. , Попов Ю. П. Оценка параметров деревьев лесных экосистем в зависимости от почвенно-климатических условий // Сельскохозяйственные науки. №8, 20.07.2017

Bogolitsyn K.G. et. al. 2016. Application of steam explosion as a method of wood matrix thermochemical activation // Journal of the Indian Academy of Wood Science. - 2016. - Vol. 13, N 1. – P. 82. DOI: 10.1007/s13196-016-0169-3. URL: https://link.springer.com/article/10.1007/s13196-016-0169-3

Bogolitsyn K.G. et. al. 2017. Supercritical Fluid Extraction as a Method of Thermochemical Activation of Wood Cell Walls // Russian Journal of Physical Chemistry B. DOI: 10.1134/S1990793117070053. URL: https://link.springer.com/article/10.1134/S1990793117070053.

Bogolitsyn K.G. et. al. 2015. Juniper wood structure under the microscope // Planta. - - Vol. 241, N 5. – P. 1231 DOI: 10.1007/s00425-015-2252-1, URL: https://link.springer.com/article/10.1007/s00425-015-2252-1

Korovin V., Nezvitskaya L., 2017. Структурные аномалии стебля древесных растений. Учебное пособие. LAP LAMBERT Academic Publishing. 2017. 268 с.

Kozlov V.A., Neronova Ya.A., 2017 Козлов В.А., Неронова Я.А. Особенности анатомического строения древесины сосны обыкновенной, сформированной в древостоях, возникших на осушаемых безлесных болотах // Теоретические и прикладные аспекты лесного почвоведения: Сборник материалов VII Всероссийской научной конференции по лесному почвоведению с международным участием. Петрозаводск: Карельский научный центр РАН. 2017. С. 397-401

Marjandyshev et. al., 2015. Марьяндышев П.А., Чернов А.А., Любов В.К. Анализ термогравиметрических и кинетических данных различных видов древесинного биотоплива Северо-западного региона Российской Федерации. // Известия высших учебных заведений. Лесной журнал. 2016. № 1. С. 167-179.

Neronova Ya. 2017. *Неронова Я.А.* Анатомическое строение древесины культур сосны обыкновенной, сформировавшейся после ежегодного внесения азотных удобрений на минеральной почве // *Повышение эффективности лесного комплекса: Сборник материалов III Всероссийской научно-практической конференции с международным участием. Петрозаводск: Издательство ПетрГУ. 2017. С. 169-171*

Novitskaya L., Nikolaeva N., Galibina N., Tarelkina T., Semenova L. 2016. The greatest density of parenchyma inclusions in Karelian birch wood occurs at confluences of phloem flows. // Silva Fennica. V. 50, N 3. 2016. Pp. 1461-1478. DOI: 10.14214/sf.1461

Novitskaya L.L., Shulyakovskaya T.A., Galibina N.A., Ilyinova M.K. 2018. Membrane Lipid Composition upon Normal and Patterned Wood Formation in Betula Pendula Roth // Journal of Plant Growth Regulation. 2018. P. 1–13. DOI: 10.1007/s00344-018-9794-y

Pekkoev A. N. et.al., 2017. Пеккоев А.Н., Соколов А.И., Харитонов В.А. Качество древесины культур сосны при периодическом внесении азотных удобрений на песчаных почвах // Теоретические и прикладные аспекты лесного почвоведения: Сборник материалов VII Всероссийской научной конференции по лесному почвоведению с международным участием. Петрозаводск: Карельский научный центр РАН. 2017. С. 405-408

Priroda Rossii. 2018. Природа России. Национальный портал. http://www.priroda.ru/regions/forest/index.php?FO_ID=600&SECTION_ID=586

Report 2016. Программа научно-технической конференции Санкт-Петербургского государственного лесотехнического университета по итогам научно-исследовательских работ 2016 года. СПб:СПбГЛТУ, 2016. С. 14-15, 17-19.

Report 2017. Программа Научно-технической конференции Санкт-петербургского государственного Лесотехнического университета по итогам Научно-исследовательских работ 2017 года. СПб:СПбГЛТУ. С. 9-10, 15-16.

Sokolov A. I. et. al. 2018 (*Соколов А.И., Пеккоев А.Н., Неронова Я.А., Харитонов В.А. Растительные ресурсы. Т. 54, № 2.* Влияние удобрений на развитие Pinus sylvestris (Pinaceae) на гарях.

Tarelkina T.V., Novitskaya L.L., Nikolaeva N.N. 2018. Effect of sucrose exposure on the xylem anatomy of three temperate species. // IAWA Journal. V. 39, N 2. 2018. Pp. 156-176. DOI: 10.1163/22941932-20170198

POTENTIAL FOR VISUAL GRADING OF TILING AND CLADDING BATTENS FROM BRITISH SPRUCE

Authors: Dan Ridley-Ellis*, Thibault Feltrin, Stefan Lehneke and Steven Adams

About the corresponding (presenting) author:

DAN RIDLEY-ELLIS

WWW.NAPIER.AC.UK

D.RIDLEYELLIS@NAPIER.AC.UK;
+441314552449

MOTIVATION

Cladding and tiling battens are not structural timber, but they sometimes need to be designed to ensure correct performance for criteria such as strength, deflection, fire and fastener holding capacity. Currently, the design in UK and Ireland is a combination of standard spans and cross-sections based on historical practice and visual grading rules in standards. There is no formal reason why these battens cannot be produced under the harmonised standard for structural timber, EN14081, but there are few current options due to their small dimensions, and this may be unnecessarily complicated and expensive for typical use.

This paper summarises the results from testing 878 British spruce battens. Knots, slope of grain and ring width were measured prior to testing to obtain bending strength, stiffness and density. It addresses the questions: 'is British spruce suitable for cladding and tiling battens?' and 'are the current rules within the standards appropriate and effective?'

EXPERIMENTAL

The specimens are British spruce: the mixture of Sitka and Norway spruce (*Picea sitchensis* and *abies*) grown in Ireland and the UK. In the past it was used for cladding and tiling battens, but recent revisions of standards made it uneconomic due to very high reject rates.

The timber was sourced from sawmills in Scotland, Wales and Ireland and had nominal cross-sections: 22x47, 35x47, 44x47, 47x47 and 27x37. This is representative of production quality in UK and Ireland, covering a width and thickness range adequate to draw conclusions about current and future standard batten sizes. The smallest sizes used in practice are 22x47 (UK) and 35x47 (Ireland).

Visual grading criteria relevant to S.R.82, BS5534 and BS4978 were measured prior to four-point bending tests to EN408 and EN384, with the worst defect positioned centrally. Density was measured on a piece cut from the specimen, which was also used to measure moisture content by the oven dry method. This approach is in line with EN14081.

RESULTS & DISCUSSION

In the paper we compare the yields and grading performance of the current standards and comment on how they might be improved. Ring width, or "rate of growth" is commonly assumed to be a good indicator of timber quality, but this is not really the case of British spruce, especially where knots are more influential on these relatively small sizes. Figure 1 shows plots of rings per 25 mm against bending strength, bending stiffness and density (evaluated to EN408 and EN384, including adjustment to 12% moisture content and k_h factor on strength). The black lines are linear regression (see also Table 1 for correlation coefficients) and the thick red lines show the characteristic value of the property of the battens with better ring width than this threshold (simple mean for stiffness, and fifth percentile by ranking method for strength and density). The ring width is somewhat useful for grading for stiffness and density (the characteristic increases as the rings per 25 mm threshold increases), but the strength is hardly improved at all because there are pieces with good rate of growth, but also low strength. Since strength is the limiting property in this case, this means ring width is not useful for grading the battens. The current standards for tiling battens (S.R.82 and BS5534) impose a minimum of 4 rings per 25 mm. This results in ~25% reject from growth rate alone, yet it brings only a modest increase in characteristic strength (~15%). In UK and Ireland the rotation length for British spruce sawlogs is about 30 to 35 years so this ring width limitation is quite problematic. The standards require a mean of ring width at each end, but the lower number of rings per 25 mm between the two ends is slightly better for grading (except for density). Measuring one end only is less effective.

Table 1. Coefficients of determination (R-squared, linear regression) for different ring width criteria

Rings per 25 mm	One end only	Average	Maximum	Minimum
Strength	0.11	0.13	0.11	**0.13**
Stiffness	0.21	0.26	0.22	**0.27**
Density	0.27	**0.33**	0.29	0.30

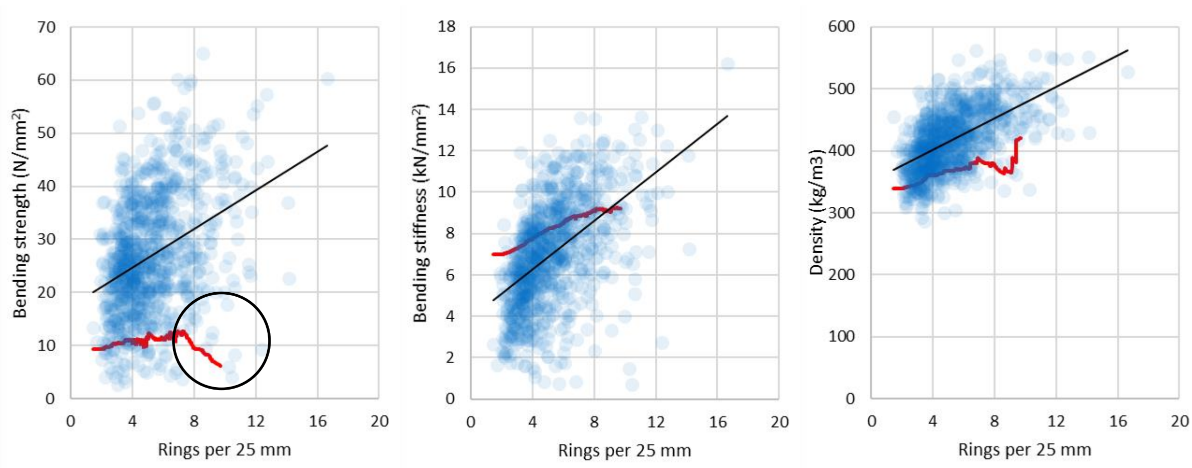


Figure 1. Bending strength, bending stiffness and density (with characteristic values) against ring width

CONCLUSIONS

The paper explores the performance of current visual grading rules for tiling battens in UK and Ireland, commenting on the properties of the timber, the ease of applying the grading rules, and how effective the rules are in improving the properties of the graded timber. British spruce can produce battens with good strength (C14 or even C16), stiffness and density, but an effective grading method needs to be found. More calculations are necessary to produce new visual grading rules in line with EN14081.

REFERENCES

BS4978:2007+A2:2017. Visual strength grading of softwood. Specification. British Standards Institution, London.

BS5534:2014+A2:2018. Slating and tiling for pitched roofs and vertical cladding – code of practice. British Standards Institution, London.

EN384:2016. Structural timber – determination of characteristic values of mechanical properties and density. European Committee for Standardization, Brussels.

EN408:2010+A1:2012. Timber structures – Structural timber and glued laminated timber – Determination of some physical and mechanical properties. European Committee for Standardization, Brussels.

EN14081-1:2016. Timber structures - Strength graded structural timber with rectangular cross section. Part 1: General requirements. European Committee for Standardization, Brussels.

EN14081-2:2010+A1:2012. Timber structures - Strength graded structural timber with rectangular cross section. Part 2: Machine grading; additional requirements for initial type testing. European Committee for Standardization, Brussels.

SR82:2017. Slating and tiling – Code of practice. National Standards Authority of Ireland, Dublin.

FEASIBILITY STUDY OF PRODUCING STRUCTURIAL MATERIALS FROM FIBROUS PLANTS BIOMASS

Authors: Dr. Inga Valentinienė

DR. INGA VALENTINIENĖ
WWW.VDA.LT
INGA.VALENTINIENE@GO.KAUKO.LT;
+3761227727

MOTIVATION

Taking the ecological problems of the “Furniture” sector into account, the goal has been not only to create ecological interior objects but an ecological material also. During the art project, an ecological, degradable, harmless material, which provokes innovative design forms, has been created from such renewable fibrous plants as flax, nettle and hemp (growing naturally in Lithuania) and patented.

The pursuit to create products (structural materials and interior eco-objects) from secondary raw materials, renewable energy sources and ecological and economical elements solves critical problems.

While seeking maximal result and analysing separate phenomena of ecological production and realization, the following hypothetical objectives, which were confirmed later on and became the fundamental supporting points in designing furniture from natural fibres, were formulated.

EXPERIMENTAL

The research object of the art project is complex and multi-layered, comprising the entire ecological manufacturing chain from the comprehension of the ecological plant’s physical and chemical composition to the solution in the production of interior eco-objects, i. e.: local fibrous plants, suitable for the production of structural materials - flax/linseed (Linum usitatissimum L.), stinging (fibrous) nettle (Urtica dioica L.) and hemp (Cannabis sativa)); the possibilities to produce structural materials from fibrous plants in Lithuania; constructive features of interior eco-objects and possibilities of their production in Lithuania; and the types of ecological interior objects in the global market.

RESOURCES: national fibrous (long-fibre) raw materials, ecological design, furniture making (traditions and/or innovations), the manufacture/technological potential of the Lithuanian furniture companies, information about the innovations in foreign furniture companies, the Lithuanian and foreign technological/scientific research base for the performance of practical tests on fibrous materials.

RESULTS & DISCUSSION

All experimental testing was conducted by strictly keeping to the boundaries of the project's aim and a strong direction: from the trial of raw materials to the formation of structural elements.

The wet process of fibreboard production suits the manufacturing of ecological sheet structural materials the most. The said process differs from the dry one, because in this case the inter-adhesion of fibres is achieved by applying chemical hydrogen bonds between the cellulose molecules instead of using adhesive substances (synthetic resins). The matrix structure secures its form and is sufficiently strong, especially in the high density fibreboards.

The performance of industrial scale testing during which hot presses were used showed that the wet process technology applied while manufacturing wooden fibreboards is suitable for manufacturing flax, nettle and hemp fibreboards. Products from fibrous plants' biomass maintain the forms obtained while pressing in their hot state and natural state (after cooling), too.

The compositional material from organic reinforcing agents and natural polymeric binders acquire features characteristic to plastic and become a low-density, light material, easily formed in high temperature and maintaining the given form in a natural state, more easily fracturing when mechanically affected by a force higher than the one intended for its exploitation, but recycled without any harm to the environment, because all its compositional elements are organic.

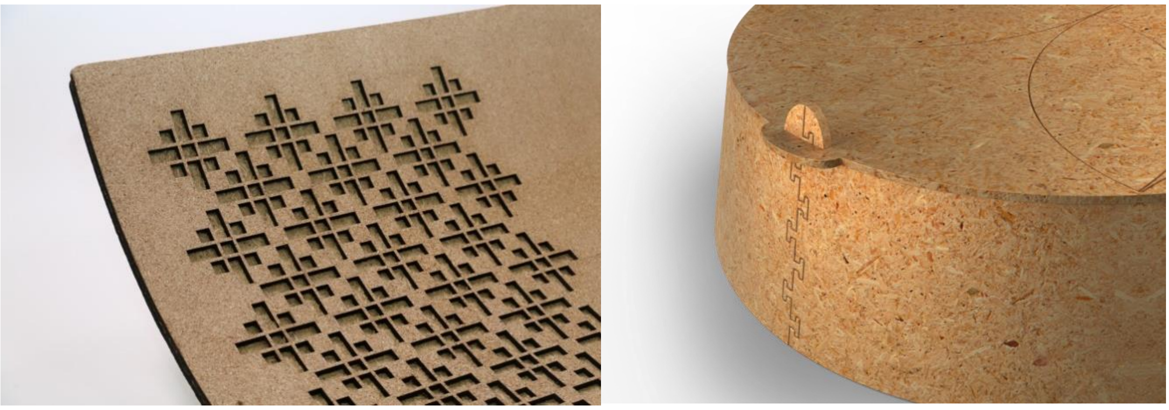


Figure 1. Examples of details forming, cutting and connecting possibilities

The following objects were created from fibrous materials: fragments – segments of furniture or other interior design objects, examples of detail connections, combinations of analogous materials and configurations of details (Fig. 1). An ecological structural material was produced and patented from fibrous materials of plant origin.

CONCLUSIONS

Such fibrous plants as flax/linseed (lot. Linum usitatissimum), stinging nettle (lot. Urtica dioica) and hemp (lot. Cannabis sativa) grow naturally in Lithuania, are alternative to wood and suitable for the manufacturing of structural materials.

The wet process technology of manufacturing wooden fibreboards is most suitable for the production of ecological sheet structural materials from flax, nettle and hemp.

Interior eco-objects of various configurations can be produced from plant fibreboard, because it is sufficiently plastic.

REFERENCES

Alberta Hemp Cost of Production and Market Assesment // Final Report (2012). Alberta: Serecon Management Consulting Inc, Edmonton.

Carus, M. (2013). The European Hemp Industry: Cultivation, processing and applications for fibres, shivs and seeds. Portugal: School of Engineering University of Minho.

Clark, I. H., Deswarte, F. E. I. (2008). Introduction to Chemicals from Biomass. WILEY.

Hongu, T., Phillips, G. O., Takigami, M. (2005). New Millenium Fibres. Cambridge: Woodhead Publishing Boca Raton [Fla] [etc]: CRC Press.

Kula, D., Ternaux, E. (2012). Materiology. Frame.

Mohanty, A. K., Misra, M., Drzal, L. T. (2005). Natural fibers, Biopolymers and Biocomposites. Boca Raton [Fla] [etc]: Taylor & Francis.

Münder, F.; Fürll, Ch.; Hempel, H. (2004). Advanced Decortication Technology for unretted Bast Fibres // Journal of Natural Fibers. The Institute of Agricultural Engineering 1 (1), pp. 49-65.

Mussing, Jorg. (2010). Industrial Applications of Naturals Fibres: Structure, properties and Technical Applications. WILEY.

Pasila, A. (2002). Harvesting and Processing of Fibre Hemp as Raw Materials for Pulp and MTF-products in Finland and Strong Composites // Production, Processing and Use of Natural Fibres, 10-11 September. – Potsdam, Potsdam-Bornim.

Pecenka, R. et al. (2012). Design of Competitive Processing Plants for Hemp Fibre Production. International Scholarly Research Network ISR Agronomy. Gemany: Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB) Potsdam, pp. 5.

Peters, S. (2014). Material Revolution // Sustainable and Multi-Purpose Materials for Design and Architecture. Publisher Birkhauser Verlag AG.

Piotrowski, St.; Carus, M. (2011). Ecological benefits of hemp and flax cultivation and products. Nova institute.

Sim Van der, R., Cowan, S. (2007). Ecological design. NW, Washington: United States of America: Island Press, Suite 300, 718Connecticut Ave., DC 20009. ISBN-13: 978-1-59726-140-1.

Sfiligoj, S.,M., Hribernik, S., Kleinschek, S., K. (2013). Plant Fibres for Textile and Technical Applications. University of Maribor.

Thoemen, H., Irle, M., Sernek, M. (2010). Wood-Based Panels. An Introduction for Specialists. Brunel University. – London: Brunel University Press.

ANALYSIS OF BEECH WOOD MILLING PROCESS USING MULTIPLE REGRESSION METHOD

Authors: Stanisław Stefanowski*, Grzegorz Pinkowski, Waldemar Szymański, Andrzej Krauss

About the corresponding (presenting) author:

STANISŁAW STEFANOWSKI

WWW.WTD.UP.POZNAN.PL

stanislaw.stefanowski@up.poznan.pl

+48797649816

MOTIVATION

Wood machining processes determine the final quality of the manufactured products [1]. Surface roughness is one of the most frequently used parameters specifying the quality of the surface [2]. The effect of machining parameters and tool wear on roughness is considerable [3] but still not precisely explained, because of numerous factors occurring in the process. Previous research concerned effects of various technological parameters on the roughness in different machining techniques [4, 5]. Furthermore, tool wear was analyzed in case of effect on the surface roughness of wood [6]. The aim of this paper was to define the effect of tool wear and feeding speed on the surface roughness of beech wood using multiple regression analysis. This approach allows to describe these dependences in more precise and systematic way.

EXPERIMENTAL

Surface roughness measurements were conducted on sample made of beech (*Fagus sylvatica* L.). Thickness of the sample was 19 mm and density was 700 kg/m^3. Laminated chipboard with density of 650 kg/m^3 was machined in order to obtain wear of the cutting tool.

Milling process was completed on Felder F900z bottom-spindle milling machine. Spindle rotational speed was 6000 min^{-1}. Knife made of cemented carbide HW, with sharpness angle of 55°, rake angle of 10°, and width of 30 mm was fixed in the four edge cutterhead. Cutting edge of the knife was blunted during milling of chipboard in range of cutting distance 0-200 m. Feeding speed and cutting depth during chipboard milling amounted 3.2 m/min and 1 mm, respectively. Surface roughness was measured along the grain and feed direction using stylus profilometer. To describe roughness of the sample, Ra and Rz parameters were calculated in accordance with ISO 4287 [7]. Milling of beech sample was carried out using four values of feeding speed: 3.2, 6.3, 12.5 and 25 m/min. Statistical analysis was done using Statistica 13.3 software.

RESULTS & DISCUSSION

Based on the obtained results of the roughness, polynomial regression models for Ra and Rz parameters were developed:

$$\boldsymbol{Ra} = 1{,}782 + 0{,}0033 * L + 0{,}175 * F - 0{,}0028 * F^2 \; (R^2 = 0{,}95)$$

$$\boldsymbol{Rz} = 9{,}667 + 0{,}0167 * L + 1{,}577 * F - 0{,}036 * F^2 \; (R^2 = 0{,}90)$$

where L – cutting distance [m], F – feeding speed [m/min].

Developed equations allow to predict values of the surface roughness of beech after milling process in aspect of effect of feeding speed and cutting distance. Comparisons between predicted and observed values of Ra and Rz parameters are shown in Fig. 1.

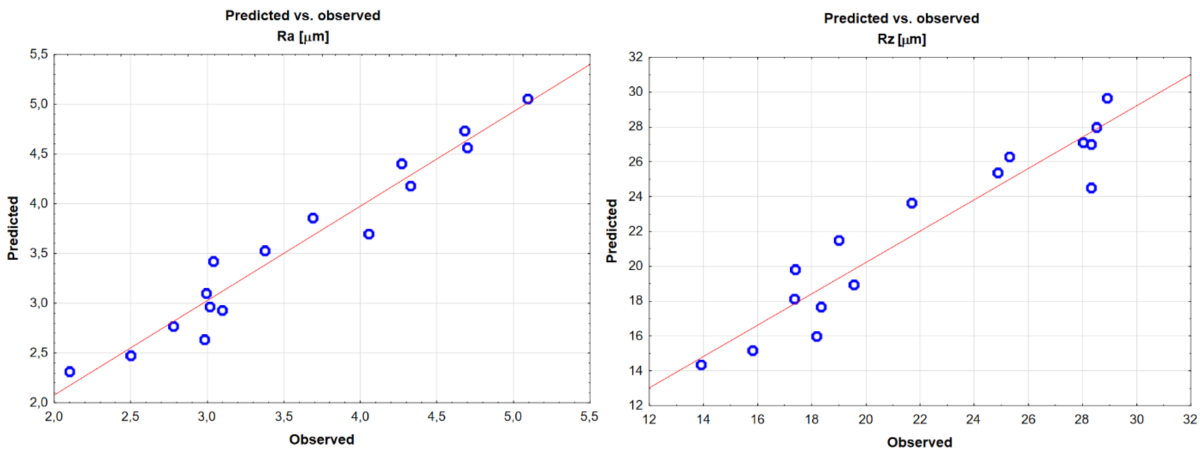


Figure 1. Comparison between predicted and observed values of Ra and Rz parameters

Dependences between the surface roughness and the technological parameters such as cutting distance and feeding speed are shown in Fig. 2. On the basis of shown graphs and developed equations found, that increasing in feeding speed and cutting distance (thus wear of the cutting edge) causes increase in roughness, but characteristic of this feature is not linear. It was stated, that effect of feeding speed on the surface roughness in more significant than effect of cutting distance.

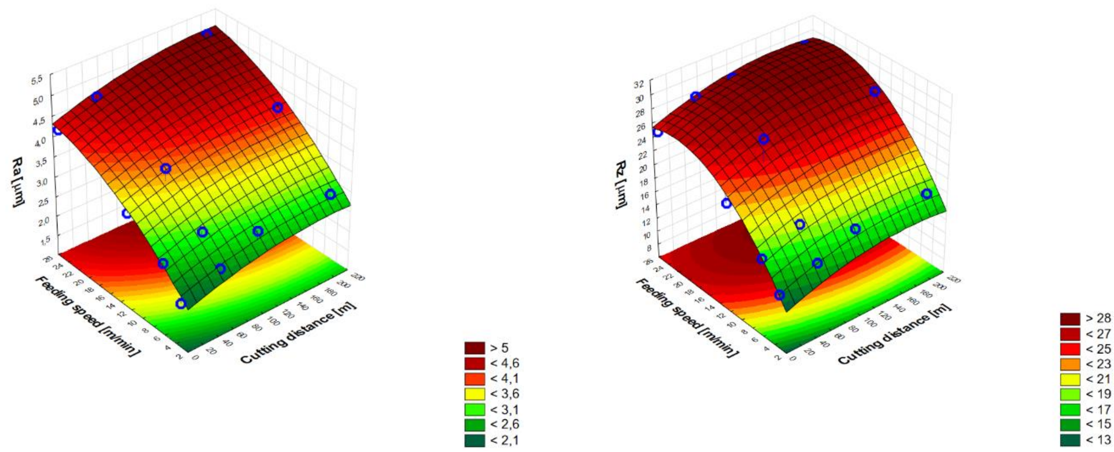


Figure 2. Dependency between cutting distance, feeding speed and surface roughness parameters

CONCLUSIONS

The surface roughness depends on numerous factors occurring in the milling process. In this experiment it has been shown, that feeding speed and cutting distance significantly affect on roughness parameters. Developed regression equations allow to state how strong each factor determinate values of Ra and Rz parameters. It can be seen, that in range of this experiment, feeding speed had more significant effect on the surface roughness than cutting distance. Some discrepancy between predicted and observed values may be caused by anatomical structure of wood, which is heterogenous and porous material.

REFERENCES

[1] Kilic, M., Hiziroglu, S., and Burdurlu, E. (2006). Effect of machining on surface roughness of wood. *Building and Environment,* 41(8), pp. 1074–1078.

[2] Salca, E.-A., and Hiziroglu, S. (2012). Analysis of surface roughness of black alder as function of various processing parameters. *Pro Ligno,* 8(2), pp. 68-79.

[3] Keturakis G., Bendikiene R., and Baltrusaitis A. (2017). Tool Wear Evolution and Surface Formation in Milling Various Wood Species. *BioResources*, 12(4), pp. 7943-7954.

[4] Malkoçoğlu, A. (2007). Machining properties and surface roughness of various wood species planed in different conditions. *Building and Environment,* 42(7), pp. 2562–2567.

[5] Škaljić, N., Beljo Lučić, R., Čavlović, A., and Obućina, M. (2009). Effect of feed speed and wood species on roughness of machined surface. *Drvna Industrija*, 60(4), pp. 229-234.

[6] Aguilera, A., Rolleri, A., and Burgos, F. (2016). Cutting distance as factor to evaluate the quality of wood machined surfaces: A preliminary study. *Maderas. Ciencia y tecnología,* 18(1), pp. 3-8.

[7] ISO 4287 (1997). Geometrical product specifications (GPS) -- Surface texture: Profile method -- Terms, definitions and surface texture parameters. International Organization for Standardization, Geneva, Switzerland.

SURVEY OF BRITISH SAWMILLS ON "ALTERNATIVE" SPECIES

Authors: Steven Adams* and Dan Ridley-Ellis

About the corresponding (presenting) author:

STEVEN ADAMS

WWW.NAPIER.AC.UK

S.ADAMS@NAPIER.AC.UK;
+441314552208

MOTIVATION

Sitka spruce will continue to be the main commercial species in the British Isles, but there are reasons to also consider wider planting of other species to better serve the aims of modern multipurpose forestry – not least a better resilience of the forest (and timber supply) to pests, diseases and climate change. There is also need to bring species that are present in the forest, but not currently managed, into the supply chain. However, little is known about the wood properties of these species when grown in Britain, and their suitability for processing in British mills. There is a lot of valuable information within the forestry and sawmill industries gained from years of practice, so a survey was undertaken to gather information about experience, perception and knowledge of processing and marketing timber from these less common forest species. This paper highlights some key findings.

EXPERIMENTAL

The survey was launched online in January 2017 using Novi Survey, a web-based survey application hosted by Edinburgh Napier University. A link to the survey along with a printable version was distributed to sawmills throughout the UK and Ireland. Questions were asked on issues relating to the logs, sawing, drying and preservative treatment. Sitka spruce, which is by far the main commercial species in the British Isles (Moore 2011), was used as the benchmark species, with the "alternative" species (Table 4) rated on a 1 to 5 scale (with 1 being worse than Sitka and 5 being better than Sitka). The candidate species were chosen after consultation with the Forestry Commission (state forestry agency in the UK) and members of the SIRT project management board representing the forestry industry. These species are also aligned to an ongoing project at Edinburgh Napier University looking at the mechanical properties of these "alternative" species (principally strength, stiffness and density). The species included 11 conifers and 3 broadleaves. Little is known about their properties when grown in the UK (Ramsay and Macdonald 2013), and research from elsewhere is of limited use because the properties are highly influenced by climate and forest management.

Table 4. The candidate species asked about in the survey along with the number of responses to each species

Species	Responses	Species	Responses
Sitka spruce (*Picea sitchensis*)	26	Noble fir (*Abies procera*)	5
Norway spruce (*Picea abies*)	15	Pacific silver fir (*Abies amabillis*)	0
Scots pine (*Pinus sylvestris*)	12	Serbian spruce (*Picea omorika*)	0
Western red cedar (*Thuja plicata*)	9	Western hemlock (*Tsuga heterophylla*)	7
European silver fir (*Abies alba*)	5	Birch (*Betula pendula / B.pubescens*)	4
Grand fir (*Abies grandis*)	8	Sycamore (*Acer pseudoplatanus*)	7
Japanese cedar (*Cryptomeria japonica*)	0	Poplar (*Populus spp.*)	3

RESULTS & DISCUSSION

The survey was split into two main sections. The first section was on general questions covering all the species and the second section was questions relating to the individual species. In total there were 44 responses to the survey and all species except Serbian spruce, Pacific silver fir and Japanese cedar had responses to the individual sections as outlined in Table 4 (this reflects their currently scarcity in British forestry, Brewer 2014 and 2016). When compared to Sitka, Scots pine was rated higher in all criteria as well as to the other species (Figure 13). Other species such as Noble fir, Norway spruce and Grand fir were rated similar to Sitka in most criteria and western red cedar was rated lower, especially with regards to preservative treatment.

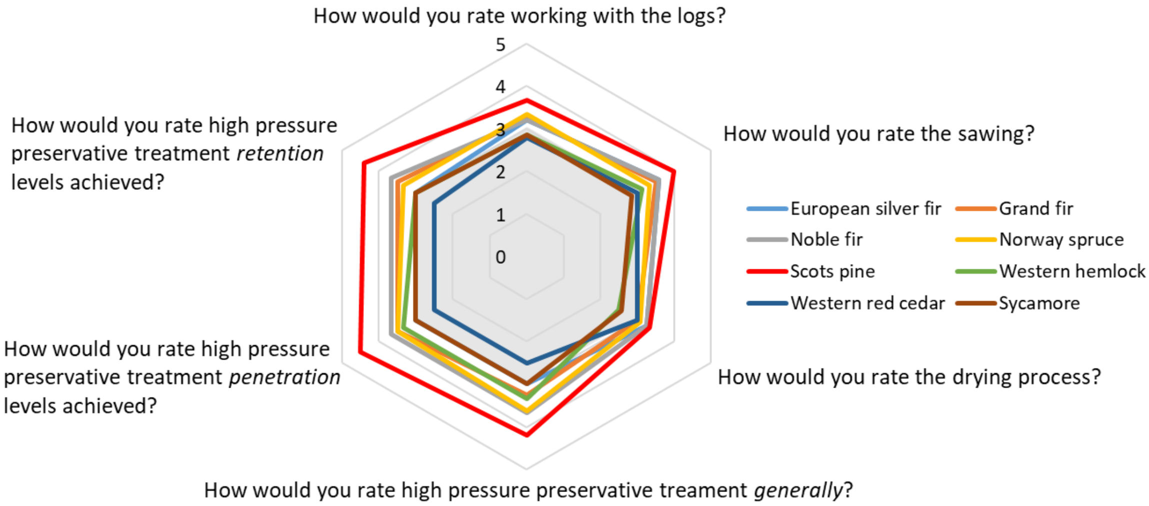


Figure 13: Average results of questions comparing various criteria of the different species to Sitka spruce. The questions were rated on a scale from 0 to 5 with 0 being worse than Sitka and 5 being better.

CONCLUSIONS

This survey gave good information from people who work in the timber industry and have experience of using these species, as well as their thoughts and perceptions of species that they hadn't used in the past. In general most respondents were open to the idea of using new species, although this was different for each species and for different respondents. This information together with information gained from research into the mechanical properties will help to inform our future research and to feedback to industry to help make informed decisions for new planting.

REFERENCES

Brewer, A. (2014). *50-year forecast of hardwood timber availability*. Forestry Commission.

Brewer, A. (2016). *25-year forecast of softwood timber availability* (NFI Interim Report). Forestry Commission.

Moore, J. (2011). *Wood properties and uses of Sitka spruce in Britain*. Forestry Commission Research Report. Forestry Commission.

Ramsay, J. and Macdonald, E. (2013). *Timber Properties of Minor Conifer Species* - A report to the Forestry Commission, Forest Research.

IDENTIFICATION OF DISTINCTIVE FEATURES FOR CASCADING WOOD WASTE IN EASTERN NORWAY

Author: Arnaud HOENNIGE, Lone ROSS GOBAKKEN, Eirik NORDHAGEN

About the corresponding author:

ARNAUD HOENNIGE

WWW.NIBIO.NO/EN

ARNAUD.HOENNIGE@AGRO-BORDEAUX.FR
+33 6 33 45 64 08

MOTIVATION

Wood was the third largest fraction of waste in Norway in 2016 [1]. 90% of wood wastes were directly recovered through energy and the 10% remaining were mainly sent to recycling [2]. The European Waste Framework Directive (2008) includes a 70% target for material recovery of Construction and Demolition (C&D) waste within 2020 [3]. There is therefore a need to develop alternative solutions for recovery of wood waste based on the principle of wood cascading. To develop strategies for recycling and re-use, it is essential to know more about the amount, the quality and the distribution of wood waste in Norway. This kind of knowledge is currently lacking. In this study we aim to identify features that could support or restrain wood waste cascading in Eastern Norway by putting into categories the stream of wood waste, by characterizing the chemical composition of wood waste and by analyzing the wood waste recovery network.

EXPERIMENTAL

Survey design

To estimate the amount of different wood waste fractions, 4.8 tons of wood wastes from 6 collecting centers were sorted into 6 quality grades. We proceeded to a two-stage simple random sampling. The data collection was performed during April and May 2018.

Laboratory tests design

Between 5 and 7 samples per wood waste grade were tested with the Inductively Coupled Plasma (ICP) technique to identify and quantify up to 29 chemical elements. The results were compared to the legal limit values for different applications. In addition, dry and ash contents were determined.

Network analysis design

The system is defined as 17 economical activities related to wood waste recovery. In the network representation, each activity constitutes a ‘node’ and each wood waste stream an ‘edge’. Nodes are connected to each other by edges. Structural and centrality indicators were defined to describe the network.

RESULTS & DISCUSSION

Results of the survey

C&D (42.0%) and wood-based panels (33.8%) are the largest fractions. Wooden packaging (8.3%) and impregnated wood (8.2%) are more or less equal. Furniture (7.7%) is the smallest fraction. The results of the survey are presented on Figure 1.

Figure 1: Proportions of wood waste, per category

C&D wood waste cascading could be improved by designing deconstruction methods [4] and by sorting on destruction sites. Furniture cascading could be improved by implementing an Extended Producer Responsibility (EPR) scheme and with preliminary designs for recycling. Wood-based panels and impregnated wood have a low potential for cascading, so it is relevant to recover them through energy. On the contrary, wooden packaging has a high potential, so it is clever to recycle it into materials.

Results of the laboratory tests

For grades B2, B3 and C1, the elements Cd, Cr, Pb and Zn prevent wood wastes from cascading into particleboards and mulch (Table 1). These excessive amounts were already found during a previous study [5] and are assumed to be due to paints, soil, metals, concrete, plastics or wood preservatives [6]. Uncertainties on contaminations could be avoided by implementing a treatment label.

Table 1: Chemical applicability of wood wastes, per grade

Application	Regulation	A	B1	B2	B3	C1	C2
Particleboard	Germany	Yes	Yes	No	No	No	Yes
	Industry	Yes	Yes	No	No	Yes	Yes
Mulch	Norway class 0	Yes	Yes	No	No	No	Yes
	Norway class I	Yes	Yes	Yes	No	Yes	Yes
	Norway class II	Yes	Yes	Yes	Yes	Yes	Yes
	Norway class III	Yes	Yes	Yes	Yes	Yes	Yes
Other	The UK	Yes	Yes	Yes	Yes	Yes	Yes

A: wooden packaging; B1: clean C&D; B2: painted/coated C&D; B3: furniture; C1: particleboard and OSB; C2: MDF and plywood

The moisture content measured in wood waste, all grades combined, is 6.31 ± 0.38 % and is therefore suitable for particleboard manufacture [7]. The ash content measured in wood waste varies between 0.36% (grade A) and 3.29% (grade B2).

Results of the network analysis

Regarding the indicators of centrality, collectors, brokers, processors and households are the core of the network. There is an interesting three-part community upstream the network. The panel and paper industries are the activities with the smallest number of stakeholders. Research & Development (R&D) should consequently be involved in the process of implementing alternative wood waste cascading solutions.

CONCLUSIONS & RECOMMENDATIONS

Table 2 briefly summarizes the main findings of the study with relevant propositions

Table 2: Main findings and recommendations

Findings	Propositions
C&D wood waste is 42.0% of the total	Design of deconstruction/disassembly methods Sorting on destruction sites
Panels and impregnated wood wastes are 42.0% of the total	Energy recovery
Wooden packaging is 8.3% of the total	Recycling or re-use but no energy recovery
Furniture is 7.7% of the total	Implementation of a global EPR scheme Preliminary design for reusability/recycling
Cd, Cr, Pb and Zn contaminations	Treatment label
Low moisture content	Feedstock for PB production
Small panel, paper and pulp industries	R&D: Development of alternative solutions

REFERENCES

[1] Waste account for Norway (1 000 tonnes), by material and year [WWW Document], 2018. . Statistisk sentralbyrå (SSB). URL https://www.ssb.no/en/statbank/table/10513/tableViewLayout1/?rxid=4298ef3d-e54d-4680- a242-d286f9a6a6cd (accessed 6.20.18).

[2] Waste account for Norway (1 000 tonnes), by treatment, material and year [WWW Document], 2018. . Statistisk sentralbyrå (SSB). URL https://www.ssb.no/en/statbank/table/10513/tableViewLayout1/?rxid=a1e3c553-47f4-4022-8a88-3e8a247ba2ab (accessed 6.20.18).

[3] European Parliament, European Council, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance).

[4] SAKAGUCHI, D., 2014. Potential for cascading wood from building (Master's thesis for the degree of Master of Science in Technology submitted for inspection, Espoo, 20 August, 2014). Aalto, Finland.

[5] CORNILLIER, C., 2005. Characterization of C&D wood waste. Presented at the 2nd Conference of COST Action E31, "Strategies Towards a Higher Technical, Economic and Environmental Standard in Europe", Topic 2 : Characteristics and standardization of recovered wood, 29-30 September 2005, Bordeaux, France.

[6] KROOK, J., MÅRTENSSON, A., EKLUND, M., 2005. Sources of heavy metal contamination in Swedish wood waste used for combustion. Waste Management 26, 158–166.

[7] IRLE, M., BARBUS, M.C., 2010. Chapter 1 – Wood-Based Panel technology, in: Wood-Based Panels - An Introduction for Specialists. Brunel University Press, London, England, p. 283.

THE FUTURE OF WOOD COMPOSITE MATERIALS AND PANEL PRODUCTS IN THE CIRCULAR ECONOMY PERSPECTIVE

Author: Dr. Graham A Ormondroyd

GRAHAM ORMONDROYD

WWW.BC.BANGOR.AC.UK

G.ORMONDROYD@BANGOR.AC.UK;
+441248 383898

About the corresponding(presenting) author: Dr. Ormondroyd completed his PhD (Wood Science) at Bangor University, UK and has been the Head of Materials Research at the BioComposites Centre for 8 years and in that time has written may proposals, papers and undertaken commercial works in all aspects of biomaterials science. Dr. Ormondroyd has over 100 publications including peer reviewed papers, conference proceedings, book chapters and edited books, he continues to publish regularly and is editing author of a new book 'Designing with Natural Materials'. Dr. Ormondroyd is a Fellow of the Institute of Materials Minerals and Mining, a member of the International Research Group on Wood Protection and in 2015 was short listed for both the Bangor and the Insider Wales Innovation Awards. Dr. Ormondroyd is an editor of 2 International Journals and a reviewer for 6 others

INTRODUCTİON

The use of timber has a large role to play in the mitigation of climate change and the reduction of carbon in the atmosphere, indeed the growing and use of timber is the original carbon capture and storage strategy.

However todays solid timber can only fulfill certain roles when construction our home and living spaces, the need for sheet materials and large spans require the use of manufactured products and composites. Composites can be produced from timber from shorter rotations and therefore have the potential for a greater long term rate of return for forestry.

This paper will begin by exploring the need for the use of timber and timber composites in the built environment and how this will have a positive effect on the reduction of carbon in the atmosphere. A brief roll call of current timber composites, their manufacture and uses will be undertaken and an assessment of their strengths, and weaknesses will be addressed.

Finally the paper will take a look to the future and the potential for new and novel composites and composite components from timber. The use of lignin and nano-cellulose will be address amongst others

CONCLUSIONS

This paper will address the past, present and future of timber composites and address their applicability to the reduction of effects of climate change.

PROPERTIES OF PARTICLEBOARDS INTENDED FOR THE PRODUCTION OF COUNTERTOPS

Authors: Radosław Mirski, Jakub Kawalerczyk*, Dorota Dziurka

About the corresponding (presenting) author:

JAKUB KAWALERCZYK

WWW.WTD.UP.POZNAN.PL

JAKUB.KAWALERCZYK@UP.POZNAN.PL

+48 664 484 312

MOTIVATION

Kitchen furniture is the most cost-effective branch of all industries from the wood furniture manufacturing group (Ellefson et al. 2010). Only in the United States, homeowners remodel upwards of 10.2 million kitchens each year and the cost of purchasing a new countertop account for 10% of kitchen remodelling total cost (Koenig 2017). According to study of The Freedonia Group (2017), global demand for countertops is projected to rise 2.3% annually through 2021, to nearly 500 million square meters, which means a continuous growth in the global production of wood-based boards. However, the manufacturing capacity in wood-based materials industry depends on the access to global resources of timber which is limited. This results from growing deficit of wood, international economic competitiveness, demographic changes etc. The previously-mentioned difficulties lead to search for the new materials that can be used for the particleboards production. The primary purpose of this work was to determine possibility of using sawmill industry by-products to manufacture innovative panels which can be used in the production of countertops.

EXPERIMENTAL

The study involved two types of experimental boards made of sawmill industry by-products (A1 and A2). For comparison purposes, commercial panels widely used for the production of countertops have been used. Properties of all variants of the tested panels are shown in Table 1.

Table 1. Properties of tested particleboards

Symbol	Type	Average thickness [mm]	Average density [kg×m^{-3}]	Type of finish
A1	Experimental	30	700.14	Raw surface
A2	Experimental	30	584.13	Raw surface
A3	Commercial	38	586.49	Raw surface
A4	Commercial	28	621.13	Raw surface
A5	Commercial	29	625.12	Laminated

The manufactured experimental panels and commercial particleboards were tested in accordance with the respective standards as listed in the followings: density in accordance with EN 323, swelling in thickness (TS) after 2 and 24 hours in accordance with EN 317, bending strength (MOR - modulus of rigidity) and modulus of elasticity (MOE) in accordance with EN 310.

RESULTS & DISCUSSION

Based on the obtained results it can be concluded that all boards (aspecially those with raw surface) were characterized by a relatively high swelling in thickness after 2 and 24h soaking in water (Fig. 1).

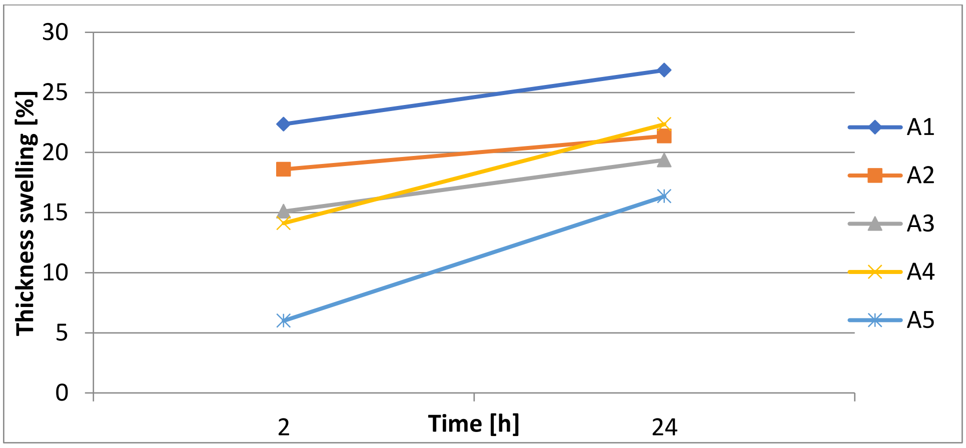


Figure 1. Thickness swelling after soaking in water

It seems that recorded values of swelling in thickness are typical for boards manufactured with no hydrophobic compounds added (Mirski et al. 2012). In the case of experimental panels, it was found that higher density boards were characterized by a larger thickness swelling. Moreover, covering the surface with a laminate effectively reduced the thickness changes due to soaking in water. As future works it would be interesting to analyze the effect of finishing the surface of the experimental panels.

On the basis of data presented in Table 2 it was found that the mechanical properties such as bending strength and modulus of elasticity of experimental panels were slightly worse compared to commercial boards.

Table 2. Modulus of elasticity and bending strength (MOR) of tested panels

Symbol	Average density [kg×m^{-3}]	MOE [N×mm^{-2}]	MOR [N×mm^{-2}]
A1	717.92	2235.14	8.57
A2	592.91	1107.43	4.14
A3	601.77	2407.92	9.50
A4	636.59	2803.33	12.27
A5	634.03	2767.11	9.71

Studies revealed that reduction of density in case of experimental boards caused a decrease in bending strength and modulus of elasticity by approx. 50%. The best results were obtained for particleboard with a thickness of 28 mm and unfinished surface. Moreover, contrary to thickness swelling results, the surface finish didn't have a significant impact on the mechanical properties of panels.

CONCLUSIONS

Research have shown that both experimental and standard panels were characterized by high swelling in thickness after soaking in water. The recorded values were much higher than those recommended by the standard. Perhaps the application of any hydrophobic agent e.g. paraffin emulsion would make it possible to decrease their swelling in thickness (Mirski et al. 2012). The experimental panels had worse mechanical properties compared to commercial particleboards. Furthermore, decrease of their density by approx. 100 kg/m^3 led to a significant reduction of bending strength and modulus of elasticity.

ACKNOWLEDGEMENTS

This study was financed by the Polish National Center for Research and Development within the framework of grant BIOSTRATEG3/344303/14/NCBR/2018.

REFERENCES

- Ellefson, P.V., Kilgore, M. A. (2010). United States Wood-Based Industry: A Review of Structure and Organization. Staff Paper Series 206. Department of Forest Resources College of Food, Agricultural and Natural Resources Sciences, University of Minnesota.
- Koenig, K.M. (2017). What's driving the cabinet & countertop industries? Trends & statistics [online]. Access: https://www.woodworkingnetwork.com/news/almanac-market-data/whats-driving-cabinet-countertop-industries-trends-statistics [12.07.2018].
- Mirski, R., Dziurka, D., Derkowski, A. (2012). Application of chips designed for particleboard core in OSB as substitute for flakes. Lignocellulose 1(1), 22-32.
- The Freedonia Group. (2017). Global Countertops by Material, Market and Type, 2nd Edition. Industry Study 3506.

EFFECT OF WATER-SOAKING-DRYING CYCLES ON WPCs WITH THERMALLY MODIFIED WOOD COMPONENTS

Authors: Susanna Källbom*, Kristiina Lillqvist, Steven Spoljaric, Kristoffer Segerholm, Lauri Rautkari, Mark Hughes and Magnus Wålinder

About the corresponding (presenting) author:

SUSANNA KÄLLBOM

WWW.KTH.SE/PROFILE/KALLBOM

KALLBOM@KTH.SE; +46732702884

MOTIVATION

There is increased interest in using biobased building materials from renewable resources along with greater demands on a more sustainable built environment [1]. The value of by-products (or components) from processing of solid thermally modified wood (TMW) could be increased by using these components in biobased building materials, e.g. wood-plastic composites (WPCs). WPCs are mostly used in exterior applications [2] and exposed to variations in humidity which can lead to extended wetting- and drying-out conditions. By replacing unmodified components in WPCs by TMW components, the maximum moisture content (MC) can be lowered, further leading to increased dimensional stability. The aim of this work was to increase knowledge about TMW components in WPCs and the objective was to study the dimensional stability and micromorphological changes as a result of water-soaking-drying cycles. Also the effect of the hot-water extraction of the components was studied.

EXPERIMENTAL

TMW and unmodified control wood (UW) components were prepared from a spruce (from Eastern Finland) board (ρ_{dry}=387 kg/m^3) cut in half where one half was modified in superheated steam (at atmospheric pressure) at a peak temperature of 210°C, 3.5 h. The components were milled and sifted into a size fraction 0.20-0.40 mm. Additionally, one sample group was hot-water extracted (HE) using an air-bath digester with rotating autoclaves (peak temperature: 140°C, 1 h).

The WPCs were prepared from the different wood component samples, polypropylene and maleated polypropylene (weight ratios 50/48/2 w%) using a Brabender Viscometer Plasti-corder PLE 651 mixer with roller-blade type impellers at 190°C, rotation speed 30 and 70 rpm during 7-9 min. The mixed material was hot-pressed at 190°C, 10 min (150 kN). Small WPC samples (15x5x2 mm^3) were cut with a table top band saw. Two 12-day-soaking-drying cycles were performed using distilled water (drying 50°C, 24 h).

RESULTS & DISCUSSION

Water absorption and dimensional stability

The water sorption was determined based on the MC of the WPC $\left(\frac{MC_{initial}-MC_{wet}}{MC_{initial}}\right)$ where the subscripts initial and wet denote the state before soaking and after 12 days of soaking, respectively. The swelling (thickness change) was determined in the same way, based on the initial and wet measured thickness values. The water absorption and swelling for the different samples (5 replicates with standard deviation) are shown in Table 1. The highest MC was observed for WPCs with UW while both the thermal modification and hot-water extraction lead to a reduced MC. Similar results were observed for WPCs, also prepared with TMW components of spruce [3]. Only a small reduction in MC was observed for WPCs with hot-water extracted TMW in comparison with WPCs with TMW components. All samples showed a higher MC after the 2nd cycle compared with the 1st soaking cycle (saturation was reached much later). During drying (50°C, 24 h) in between the cycles the MC was above 0% which means that the samples did not dry out completely. The thickness swelling was most pronounced in the WPCs with unmodified components and reduced after the 2nd soaking cycle with about 25% and 50% as a result of hot-water extraction and thermal modification, respectively. Surprisingly, the WPCs with hot-water extracted TMW components showed somewhat higher swelling values compared with the ones with TMW components.

Table 1. The MC and the thickness swelling after the 1st and 2nd soaking are shown for the different WPC samples with UW and TMW both non-extracted and hot-water extracted (HE). The results are based on 5 replicates (including standard deviation).

WPC sample	MC after 1st soaking (%)	MC after 2nd soaking (%)	Swelling after 1st soaking (%)	Swelling after 2nd soaking (%)
UW	11.2 (0.5)	12.0 (0.3)	6.6 (1.1)	7.5 (0.9)
UW/HE	6.5 (0.4)	8.9 (0.3)	3.9 (0.6)	5.6 (0.7)
TMW	3.5 (0.1)	5.1 (0.2)	2.6 (0.3)	3.7 (0.6)
TMW/HE	2.9 (0.2)	4.1 (0.3)	2.7 (0.7)	3.9 (0.8)

Micromorphology after water-soaking-drying cycles

The micromorphological changes were analysed using scanning electron microscopy (SEM) before soaking and after the 1st and 2nd cycle. Figure 1 shows the various WPC samples after the 2nd soaking-drying cycle. Interfacial cracks and cracks both in the cell wall and matrix (polymer) were observed after the 1st soaking-drying cycle and increased after the 2nd. The WPCs with UW components were most affected by the soaking-drying cycling shown by increased wood-polymer interfacial cracks, which is further in agreement with the water absorption and swelling results. A reduction of cell wall cracks and cracks in the matrix was observed for the WPCs with hot-water extracted and TMW components as a result of the reduced hygroscopicity of these components.

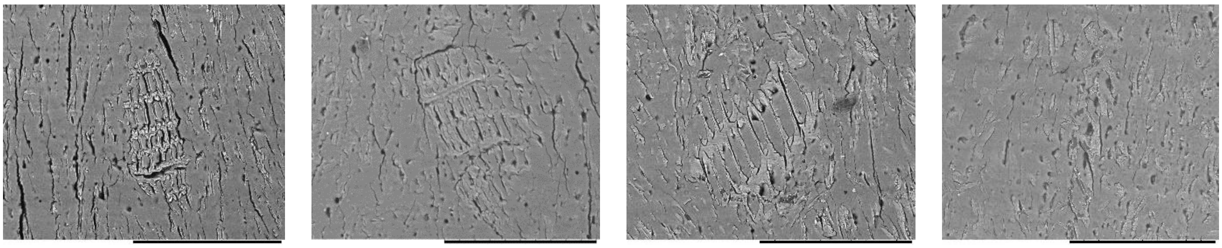


Figure 1. SEM images of the WPC samples with UW, UW hot-water extracted, TMW and TMW hot-water extracted components (from left to right) after the 2nd soaking-drying cycle. The full scale bars correspond to 200 µm.

CONCLUSIONS

The WPCs with TMW and hot-water extracted components showed a reduced water sorption and swelling compared with the WPCs with unmodified components. The micromorphological analysis indicated improved interfacial interactions for the WPCs with TMW components and also with hot-water extracted components, with less wood-polymer interfacial cracks. Thermally modified wood components (by-products) are valuable for usage in WPCs; as potential outdoor biobased building materials with increased durability.

ACKNOWLEDGEMENT

The Northern European Network for Wood Science and Engineering (WSE) is greatly acknowledged for sponsoring this work in the form of a short-term scientific mission.

REFERENCES

[1] Erlandsson, M. and Sundquist, J.-O. (2014). A Report for A Nordic Cooperation Project on the EC Recovery Target for Construction and Demolition Wast (CDW). Stockholm: IVL Report No B2182, pp. 1-29.

[2] Clemons, C., Rowell, R.M., Plackett, D. and Segerholm, B.K. (2013) Chapter 13. Wood/non wood thermoplastic composites. In: R.M. Rowell, ed., *Handbook of wood chemistry and wood composites,* 2nd ed. Boca Raton, Florida: CRC Press, pp. 473-508.

[3] Segerholm, B.K., Rowell, R.M., Larsson-Brelid, P., Wålinder, M.E.P., Westin, M. and Alfredsen, G. (2007). Improved durability and moisture sorption characteristics of extruded wood-plastic composites made from chemically modified wood. In: *9th International Conference on Wood and Biofiber Plastic Composites*. Madison, WI: Forest Products Society, pp. 253-228.

THE EFFECT OF COUPLING AGENT ON THE PROPERTIES OF HEAT TREATED WOOD PLASTIC COMPOSITES

Authors: Edgars Kuka*, Dace Cirule, Janis Kajaks and Bruno Andersons

About the corresponding (presenting) author:

EDGARS KUKA

WWW.KKI.LV

KUKINSONS24@GMAIL.COM

MOTIVATION

Wood plastic composites (WPC) have gained a relatively large share in the composite market. The environmental benefits and good properties of the materials make them attractive for variety of applications. The largest interest and the most promising market growth is predicted for the automotive industry followed by the building and construction industry [1]. Because of the hydrophilic nature of wood and characteristics of non-polar thermoplastic polymer, there are some challenges that restrict the full potential of these materials. The main challenges are water absorption, fungal attacks, UV degradation, dimensional changes, creep, mechanical properties, fire performance and cost [2]. By using different additives (coupling agents, pigments etc.) or by modifying the wood particles (chemically or physically) it is possible to improve some of the properties, however any additional operation increase the cost of the product. One of the most promising ways to overcome some of these challenges without significantly increasing the costs is the use of wood residues from heat treated lumber. Previous research about heat treated wood plastic composites (HTWPC) show that these materials have superior water resistance, dimensional stability, creep resistance, durability against fungi and even better thermal stability than WPC with untreated wood particles [3, 4, 5]. One of the major disadvantages for HTWPC are the mechanical properties which could be improved by using coupling agents. Of course the addition of coupling agent increase the cost of the end product, however still the manufacturing costs for HTWPC should be in the same range as any other commercial WPC, because most of them contain coupling agents. The main objective of the research was to determine how maleic anhydride-grafted polypropylene (MAPP) influence HTWPC properties.

EXPERIMENTAL

Wood particles were obtained by milling untreated and heat treated pine (*Pinus sylvestris*) boards. Before compounding, the wood particles were dried in 103±2°C for 24 h. WPC were made with a two-roll mill and the chosen compositions are shown in Table 1. Injection moulding (T = 180°C, P = 2.5 MPa) was used to prepare bar samples for flexural, impact strength, water absorption, dimensional stability and soaking-drying cycle measurements. Flexural properties and impact strength were determined according to EN ISO 178 and EN ISO 179, respectively. Water absorption and dimensional stability for WPC samples immersed in water was determined by measuring the water uptake and volume change at defined intervals up to 200 days. Soaking-drying cycle experiment was done to determine changes in WPC that are caused by swelling and shrinking of wood particles. One soaking-drying cycle involved: WPC sample immersion in water for 5 days and subsequent drying in an oven for 2 days. After 7 soaking-drying cycles flexural properties were determined.

Table 1. Composition of the tested wood plastic composites

WPC type abbreviation	Formulation abbreviation	Untreated (U) wood particles, wt-%	Heat treated (HT) wood particles, wt-%	Polypropylene (PP), wt-%	MAPP, wt-%
UWPC	U(50:50)	50	-	50	-
	U(50:47:3)	50	-	47	3
HTWPC	HT(50:50)	-	50	50	-
	HT(50:47:3)	-	50	47	3
HTWPC*	HT(40:60)	-	40	60	-
	HT(40:57:3)	-	40	57	3

RESULTS & DISCUSSION

Coupling agents are used to improve the adhesion between wood particles and polymer matrix which results in enhancement of mechanical and physical properties [6]. The effect of MAPP on mechanical properties for untreated wood plastic composites (UWPC) and HTWPC are presented in Table 2.

Table 2. Mechanical and surface properties of wood plastic composites

Formulation abbreviation	Flexural properties		Micro-hardness (Vickers), MPa	Impact strength, kJ·m^{-2}
	MOR, MPa	MOE, GPa		
U(50:50)	37 ± 1	3.5 ± 0.1	109 ± 11	5.6 ± 0.4
U(50:47:3)	59 ± 1	4.1 ± 0.2	111 ± 11	9.0 ± 1.0
HT(50:50)	40 ± 1	4.2 ± 0.2	139 ± 14	4.5 ± 0.5
HT(50:47:3)	66 ± 4	4.8 ± 0.4	145 ± 15	8.0 ± 1.2
HT(40:60)	42 ± 2	3.7 ± 0.2	108 ± 9	5.3 ± 0.6
HT(40:57:3)	62 ± 4	3.9 ± 0.3	111 ± 10	9.7 ± 1.4

The results show that impact and flexural strength are the most affected by addition of MAPP. For UWPC the impact strength and MOR values increased by 61 % and 59 %, respectively. However for HTWPC the increase was even more significant reaching 78 % and 65 %, respectively. The results suggest that MAPP efficiency is larger in case of HT wood particles. Similar conclusions have been made in different study regarding tensile strength [7]. The stiffness of the WPC is affected as well, however the influence is significantly smaller. The only tested property that was not affected by addition of MAPP was micro-hardness. The results are also similar for HTWPC with smaller wood particle content (40 wt-%). The results regarding water resistance showed (not presented) that by addition of MAPP it was possible to reduce the water uptake by 47 % for UWPC, by 57 % for HTWPC and by 40 % for HTWPC*. The improvement for HTWPC* is significantly smaller because initially HTWPC* without coupling agents have excellent water resistance properties (3.7 % water uptake after 200 days in water). The same trend was observed for dimensional stability (not presented).

In the outdoor environment WPC are subjected to fluctuations in moisture content that can cause a significant damage because of the swelling of wood particles which can result in reduced mechanical properties, reduced fungal resistance and reduced water resistance of the composite. To identify changes during soaking-drying cycle experiment the mass was measured and mass change was calculated. The results regarding the test are shown in Figure 1. The mass change is noticeable in both directions. Mass gain is because of the absorbed water, however mass loss is because of the water soluble extractives that are extracted in the process from the wood particles. The most significant changes in mass gain after 7 cycles was observed for UWPC without MAPP (increased from 3.2 % to 5.9 %) followed by UWPC with MAPP (increased from 1.7 % to 2.2 %). For all of the HTWPC the mass gain over time did not change, which indicates that these composites are much more resistant to such fluctuations in moisture content. Flexural properties after soaking-drying cycle were determined for these samples and the results showed (not presented) that for all WPC without MAPP flexural properties decreased, however the decrease for HTWPC was significantly smaller. Interesting results were observed for all WPC with MAPP where the flexural strength increased after soaking-drying experiment. That could be because, in the presence of water, the surface -OH groups of the swollen wood may reach the unreacted MAPP molecules and in the result form an ester bond.

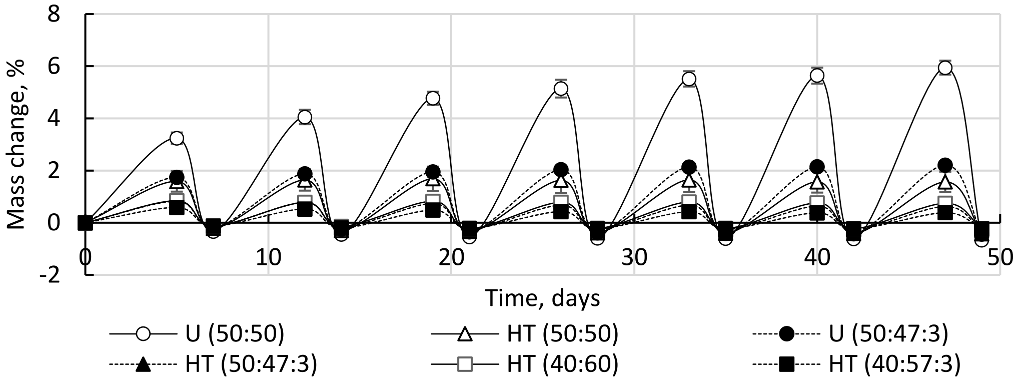


Figure 1. Mass change (%) of wood plastic composites during soaking-drying cycle experiment

CONCLUSIONS

From the results it can be concluded that HTWPC without MAPP are equivalent to UWPC with MAPP when regarding water resistance. By addition of MAPP it is possible to significantly improve most of the HTWPC properties especially flexural and impact strength. Also the results suggest that MAPP efficiency is larger when it is used with HT wood particles than with untreated wood particles.

REFERENCES

1. Dwivedi, D. (2017). Wood Plastic Composites Market by Type (PE-based Composites, PVC-based Composites, PP-based Composites, and Others) and Application (Building & Construction, Automotive Components, Industrial & Consumer Products, and Others) - Global Opportunity Analysis and Industry Forecast, 2017-2023. Allied Market Research, 220 p.

2. Warnes, J. (2008). Wood Plastic Composites.

3. Kaboorani, A. and Fazipour, M. (2009). Effects of Wood Preheat Treatment on Thermal Stability of HDPE Composites. *Journal of Reinforced Plastics and Composites*, 28(24), pp. 2945-2955.

4. Yang, T.C., Chien, Y.C., Wu, T.L., Hung, K.C. and Wu, J.H. (2017). Effect of Heat-Treated Wood Particles on the Physico-Mechanical Properties and Extended Creep Behavior of Wood/Recycled-HDPE Composites Using the Time-Temperature Superposition Principle. Materials, 10(4), 365.

5. Kuka, E., Cirule, D., Kajaks, J., Janberga, A., Andersone, I. and Andersons, B. (2017). Fungal Degradation of Wood Plastic Composites Made with Thermally Modified Wood Residues. *Key Engineering Materials*, 721, 8–12.

6. Lu, J.Z., Wu, Q. and McNabb Jr., H.S. (2000). Chemical Coupling in Wood Fiber and Polymer Composites: A Review of Coupling Agents and Treatments. *Wood and Fiber Science*, 32(1), 88-104.

7. Kaboorani, A., Faezipour, M. and Ebrahimi, G. (2008). Feasibility of Using Heat Treated Wood in Wood/Thermoplastic Composites. *Journal of Reinforced Plastics and Composites*, 27(17), 1689-1699.

INFLUENCE OF BİRCH FALSE HEARTWOOD ON THE PHYSİCAL AND MECHANİCAL PROPERTİES OF WOOD-PLASTİC COMPOSİTES

Authors: Heikko Kallakas*, Gbenga Solomon Ayansola, Tanel Tumanov, Dmitri Goljandin, Triinu Poltimäe, Andres Krumme and Jaan Kers

About the corresponding(presenting) author:

HEIKKO KALLAKAS

WWW.TALTECH.EE

HEIKKO.KALLAKAS@TALTECH.EE
+3726202910

MOTIVATION

This research investigates the properties of the wood-plastic composites, which are made of polypropylene matrix and birch wood as a filler. Wood plastic composites have already been widely researched materials and these materials are often used in commercially. There are many researches about the mechanical and physical properties of the wood-plastic composites and durability of these materials. However, there is no research about the effect of birch wood quality on the properties of wood-plastic composites. This is a wood defect common to birch and other wood species such as beech, maple, ash, poplar, linden etc. and its occurrence increases with the aging of the tree. The use of this false heartwood has often been a concern to the wood industry in view of the problems associated with its use which leads to lot of wastages of birch wood. This research therefore seeks to investigate the use of birch false heartwood as a filler material in wood-plastic composite. The specific objective of the study is to investigate the effect of birch false heartwood on the physical and mechanical properties of wood-plastic composites. Comparison of the results obtained will be made with pure birch wood-based composites.

EXPERIMENTAL

Polypropylene (PP) PPH 11012 nucleated controlled-rheology antistatic homopolymer obtained from Total Petrochemicals USA Inc was used as matrix material. The birch wood (both the pure wood and the false heartwood, supplied by Kohila Vineer OÜ) was used as filler material. For modification of the wood particles, the wood particles were treated with 5.0 wt% (by wood content) sodium hydroxide (NaOH) and 5.0 wt% (by wood content) 3-aminoprophl-triethoxysilane (APTES). The wood particles were mixed with the PP in the ratio 60 wt% of wood to 40 wt% of PP for all samples made. The composites were compounded in the co-rotating twin-screw extruder. The test samples were made by injection moulding according to EN ISO 527-2. Mechanical properties of the WPC-s were tested with tensile test (EN ISO 527-2), 3 point bending test (EN ISO 178) and Charpy impact test (EN ISO 179-1). Physical properties were tested with water absorption and thickness swelling and UV-aging tests. The compositions of the composites were analyzed using Fourier Transform Infrared Spectroscopy (FTIR).

RESULTS & DISCUSSION

Composition of the composites is shown on Table 1. The results showed that the tensile strength of all the samples reduced after absorption of water. FHW and MFHW had close tensile strength before soaking in water but after absorption of water, MFHW had a 10.17% higher decrease in tensile strength than the FHW. This shows that the addition of 5 wt% NaOH and APTES did not affect the tensile strength of the FHW to cause an increase and it suggest that the silane was not able to penetrate through the bonds of the false heartwood to enable the interfacial adhesion of the composite. The flexural strength of FHW and MFHW were about the same before soaking in water. However, the effect of APTES 5 wt% modification is visible in the flexural strength of MFHW composites after soaking in water. The false heartwood composite showed the lowest reduction of 10.6% in flexural strength and the modified false heartwood showed the highest reduction of 16.6% in flexural strength after absorption of water. This indicates that MFHW absorbed water more than FHW. MFHW had the highest decrease in flexural MOE. Modification with 5wt% silane and NaOH increased the water absorption of MFHW and MP composites. This increase is more for MFHW by 28% and less for modified pure at 4.3%. The modified false heartwood has the highest absorption of 17.26. Absorption of water reduced the impact strength of all composites. UV radiation degraded the neat PP and all the composites. Surface chalking was observed in all WPCs exposed to artificial weathering with colour ranging from brown and brownish black to white. Modified pure birch and modified false heartwood had about the same colour change at the end of the 2016 h which were the greatest change in colour among the composites.

Table 1. Composition of the composites

Sample	PP wt%	Birch wt%	NaOH wt%	APTES wt%
PP	100	—	—	—
PB	40	60	—	—
MPB	40	60	5	5
FHW	40	60	—	—
MFHW	40	60	5	5

PP- Polypropylene
PB- Pure Birch
MPB- Modified Pure Birch
FHW- False Heartwood
MFHW- Modified False heartwood

CONCLUSIONS

This research was conducted to investigate the influence of birch false heartwood on the physical and mechanical properties of wood-plastic composite. The use of birch false heartwood in the manufacturing of WPCs has been shown to be promising. However, the modification of the birch false heartwood should be improved in further studies to maximize its capabilities in the production of WPCs.

INVESTIGATION OF WOOD BOARDS FROM TEXTILE WASTE, WOOD AND HEMP FIBRES

Authors: Giedrius Pilkis*, Valdas Norvydas and Vaida Jonaitiene

GIEDRIUS PILKIS
WWW.KTU.LT
GIEDRIUS.PILKIS@KTU.EDU; +37069870063

MOTIVATION

Nowadays, very popular in a variety of sustainability concepts and activities, which occupies an important place in waste recycling. Wood is cutting in the recycling process and the product is wood panels. Recycling of non-hazardous solid textile waste may be viable alternative for industries. Recycling is the reprocessing of waste materials into new or reusable products. Ninety-nine percent of used textiles are recyclable, but only 20 % textile waste is recycled and 80 % goes to landfills. This waste is appropriate recycled into new products - production of raw materials suitable. Wood boards materials made from renewable resources, such as wood, hemp and textile waste, play an important role in the sustainable development of society.

Goal of the research directed to development the optimal composition award, forming wood boards of wood, hemp and textile waste, as characterized by new functional characteristics and investigate moisture setting for wood boards.

EXPERIMENTAL

For the production of wood boards, as was the use of fine-cut pulp textile waste obtained from the company "Neaustima" UAB. Minced hemp fiber is obtained from Lithuanian hemp growers - processing companies (Figure 1). The AsWood 7502 hardener and AsWood 7000 resin were also used.

Figure 1. Materials used in the production of wood boards: a - textile waste, b - minced hemp fiber.

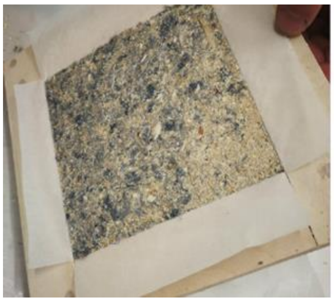
RESULTS & DISCUSSION

In the production of wood boards, samples of three different groups were produced, the composition of the wood boards made is presented in Table 1.

Table 1. Wood boards composition

Wood panels group	Machine used in production	Composition
Panel A	Joos LAP 40 (Gottfried Joos Mschinenfabrik, Germany) press	80 % wood sawdust, 20 % textile waste
Panel B	Joos LAP 40 (Gottfried Joos Mschinenfabrik, Germany) press	90 % wood sawdust, 10 % textile waste
Panel C	Joos LAP 40 (Gottfried Joos Mschinenfabrik, Germany) press	100 % hemp fibre

Three different groups of samples (Figure 2) were produced during the production of wood boards, which were subjected to moisture determination.



Panel A

Panel B

Panel C

Figure 2. Wood boards photos.

Table 2. Moisture setting for wood boards

Wood panels group	Initial mass of the section, g	Mass of the section, after 60 min, g	Mass of the section, after 90 min, g	Mass of the section, after 120 min, g	Absolutely dry mass of section, g	Initial section moisture, %
Panel A	18,00	16,68	16,56	16,50	16,40	8,89%
Panel B	30,96	28,56	28,02	27,78	27,54	12,42%
Panel C	27,24	25,58	25,10	24,76	24,40	11,64%

REFERENCES

1. Guignier, C. Textile Recycling: An Overview on Technologies and Tendencies Applications. International Textile & Apparel Association (2013), Vol 24 No 3 p1–14.
2. Environmental Protection Agency. Internet access: http://gamta.lt/cms/index.
3. Smith-Heisters, S. 2008. Illegally Green: Environmental Costs of Hemp Prohibition. Policy Study 367, p. 44.
4. Jonaitienė V, Jankauskienė Z and Stuogė I 2015 Hemp cultivation opportunities and perspectives in Lithuania Natural fibres: advances in science and technology towards industrial applications: from science to market vol 12 eds Raul Fangueiro, Sohel Rana (Dordrecht: Springer) p 407.

HYGROTHERMAL PERFORMANCE OF CROSS-LAMINATED TIMBER WALLS WITH INTERIOR INSULATION

Authors: Villu Kukk*, Jaan Kers and Targo Kalamees

About the corresponding (presenting) author:

VILLU KUKK

EARLY STAGE RESEARCHER

WWW.TALTECH.EE

VILLU.KUKK@TALTECH.EE;

+372 620 2402

MOTIVATION

Moisture safety is as important for CLT envelopes as for any other building envelopes. For wood, mould growth is usually the first criteria for limiting moisture conditions that are too high. Considering the surface area and mass of the CLT used in building envelopes compared to the other wood frame structures, the time for excess moisture drying is potentially longer and therefore the risk of mould growth is higher.

This study was intended to determine the maximum allowable initial moisture content as a performance criterion for CLT walls having both exterior and interior thermal insulation.

EXPERIMENTAL

A laboratory test was conducted with different initial moisture contents for the CLT panels that were tested. The additional purpose of this study was to create and validate a simulation model of the test walls for hygrothermal simulations. Laboratory tests and simulations were used to determine the allowable initial moisture content for CLT panels.

Four test walls with two different insulation solutions and two different initial moisture contents were built. The difference in structures lay firstly between the vapour resistance of the interior thermal insulations of the respective CLT panels. In one case a 25 mm thick mineral wool plate with variable water vapour resistance (Vario InLiner by Isover) was used and in the second case a 30 mm thick rigid polyisocyanurate (PIR) insulation having a high water vapour resistance (Kingspan Therma TP10 with aluminum foil surfaces), see Figur a. Two different initial moisture content (MC) levels for the panels were used: ~20% and ~13%. The test walls were installed in a climate chamber. No mould growth (M<1) was used as the performance criteria. The test was conducted for Nordic climate conditions from autumn to spring. The test duration was 86 days and during the test period the data for relative humidity and temperature in different layers of the test walls was collected, see 1b. Based on the results of the experiment a simulation model for the test walls was created and validated.

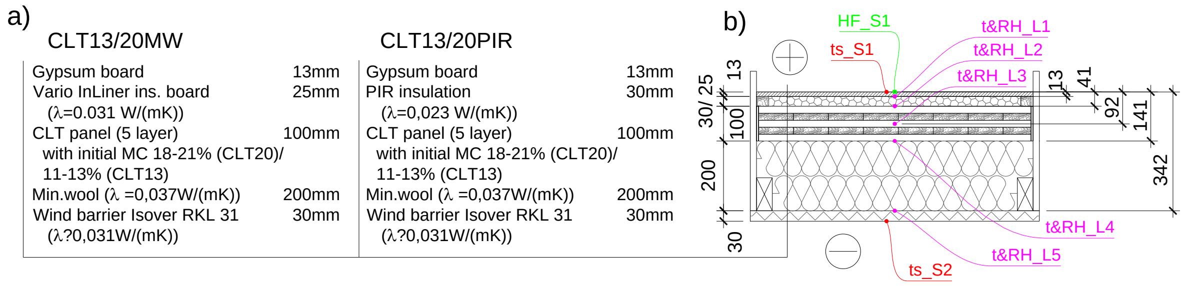


Figure 1. Material layer lists of the test walls (a) and placement of measuring sensors in the wall section (b).

RESULTS & DISCUSSION

The results from the validated calculation models showed that the maximum allowable initial MC of the CLT panels was 17% for wall assembly CLTMW where excessive moisture from the CLT panel could dry out across two sides, both to the interior and exterior, see **Error! Reference source not found.** a. For wall a ssembly CLTPIR where drying out was only possible to one side (exterior) the maximum allowed value for the initial MC in CLT panels was 15%, see **Error! Reference source not found.** b. The results from measurements and calculations showed that using a mineral wool plate with variable water vapour resistance as an interior insulation in the CLT walls is a hygrothermally safer solution than using PIR insulation that has a high water vapour resistance. For construction timber, strictly monitored for glue laminated timber, the allowable MC is between 8-15% and therefore using a PIR board as interior insulation for CLT walls should be done with more caution because of the very small margin for error.

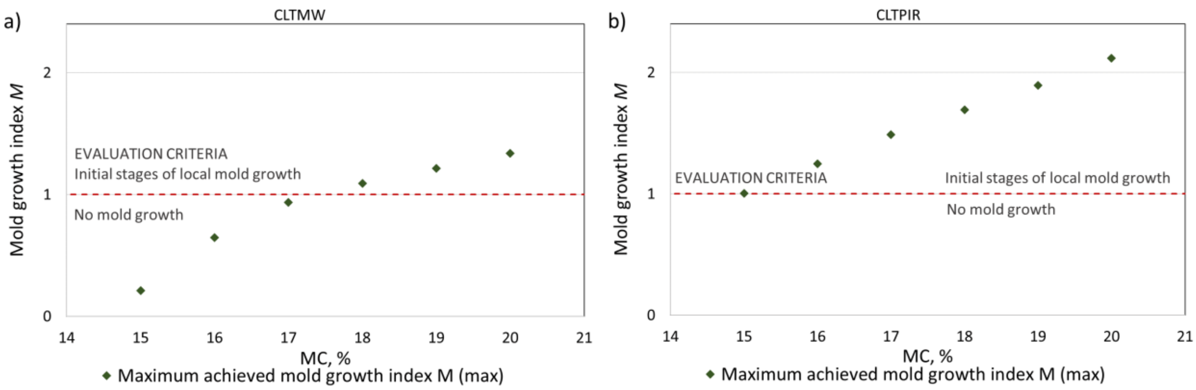


Figure 2. Maximum achieved mold growth index for different initial MC in CLT panel in wall assembly CLTMW (a) and in CLTPIR (b) during five year calculation period.

Calculation results also showed that if walls were insulated from the interior in such a way that excess moisture from CLT could dry out across two sides (CLTMW) then the most favourable month for covering was June and the most unfavourable, December. If walls were insulated from the interior in such a way that excess moisture from CLT could dry out only to one side, to exterior (CLTPIR), then there were no considerable difference in which month to cover.

CONCLUSIONS

Test and simulation results were analyzed and main following conclusions were made: the maximum allowable initial MC of the CLT panels was 17% for wall assembly CLTMW and for wall assembly CLTPIR it was 15%. The most unfavourable month to cover the CLT panels with interior insulation for wall assembly CLT13MW was December and for CLTPIR there were no considerable difference.

ENVIRONMENTAL PERFORMANCE OF CONSTRUCTION STAGE FOR GLUE AND CROSS LAMINATED TIMBER

Authors: Lars G. F. Tellnes* and Kristine Nore

About the corresponding(presenting) author:

LARS G. F. TELLNES

WWW.ostfoldforskning.NO

lars@ostfoldforskning.no

+4740013697

MOTIVATION

Laminated timber products (Gluelam and CLT), are increasingly used as structural building materials. The motivation is often based on the environmental performance of low carbon footprint in manufacturing and indoor climate during use. The use of glulam and CLT can also have benefits for transport to building site and during construction. The low weight makes it possible to transport more of the required materials and use smaller cranes, compared to heavier materials such as steel and concrete. During installation, the building time is typically reduced compared to steel and concrete solutions, which can lead to reduced energy use. The objective of the paper is to investigate the importance of the construction phase in the carbon footprint of laminated timber products.

EXPERIMENTAL

A comparison on the carbon footprint of typical glulam and CLT products on the Norwegian market was performed. Life cycle phases included are cradle-to-gate, transport to building site and installation. Environmental product declarations (EPD) from EPD-Norway was used as source for the carbon footprint of the manufacturing. Not all EPDs included the transport to building site and installation phase, so these where then based on data from on of the EPDs which included this information. For all products, the transport to building site was adjusted to a building site in Oslo. Since the end-of-life phases was not included, the biogenic carbon uptake by forests was accounted with instantaneous oxidation. The products included, and their scenarios are listed in in Table 1.

Table 1. Description of scenarios for transport to building site and installation used in the comparison per functional unit of 1 m³ product installed

Manufacturer	EPD nr.	Transport to building site in Oslo	Wastage in installation	Packaging	Energy
Cross timber systems (CLT)	NEPD-1269-410	1200 km	0 %	14 kg	0.27 kWh electricity
Moelven Limtre (Glulam)	NEPD-1577-605	200 km	0 %	0,71 kg	0.27 kWh electricity
Sørlaminering (Glulam)	NEPD00263	300 km	0 %	-«-	-«-
Martinsons Såg AB (Glulam)	NEPD-346-236	940 km	0 %	-«-	-«-
Martinsons Såg AB (CLT)	NEPD-345-236	940 km	0 %	-«-	-«-
Moelven Töreboda (Glulam)	NEPD-456-318	335 km	0 %	-«-	-«-

RESULTS & DISCUSSION

The results of the carbon footprint of the products are shown in Figure 1. The results show that product stage is the most important for the carbon footprint (54-91 %), while transport to building site has some contribution (9-46 %), the installation is minimal (<1 %).

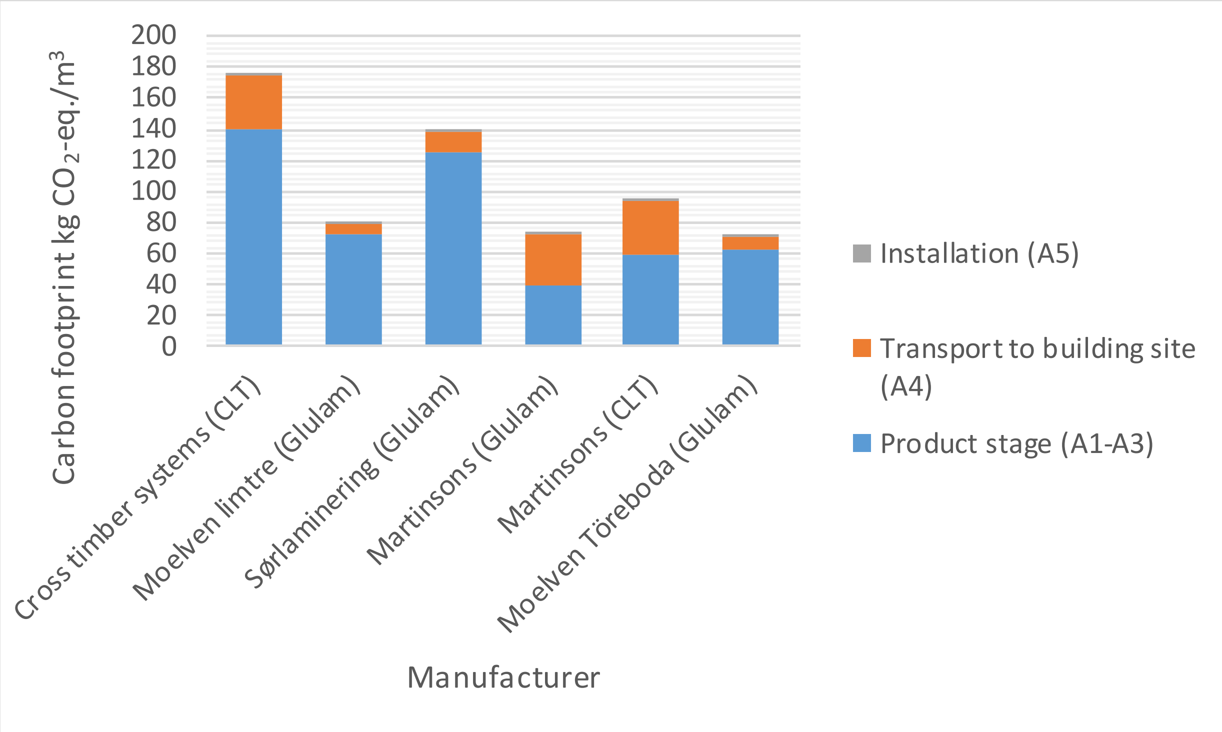


Figure 1. Carbon footprint on glulam and CLT including product stage (A1-A3), transport to building site (A4) and installation (A5)

The transport stage can for some producers be almost as important as the manufacturing and thus this should be a requirement in comparisons of products. The impact per km of transport did however vary between some of the EPDs and harmonization of the calculation of transport is needed. The construction stage has little importance, but more uncertain if it is completly declared.

CONCLUSIONS

The comparison has shown that the carbon footprint of different laminated timber products has a major difference in manufacturing. For transport to building site, this can be quite low in some cases, but almost as important as manufacturing in other cases. The building site contribution has shown low contribution, but further investigation is needed to find out if this is completely declared. The review has shown that few EPDs include transport to building site and installation phase for glulam and CLT. The low contribution of laminated timber products during construction can be a benefit compared to steel and concrete as structural building materials. In Oslo the use of fossil free building sites is becoming more common. Wood can simplify this target by the reduced weight and nearly no need for drying of the completed building. The environmental performance of construction stage of structural building materials needs further investigation to standardize the scope and is needed to show the total environmental performance over the life cycle of these products.

REFERENCES

Cross timber systems Ltd. (2017). Environmental product declarition of Cross laminated timber panels. Oslo: The Norwegian EPD Foundation.

Martinsons Såg AB (2015). Envrionmental product declaration for cross laminated timber. Oslo: The Norwegian EPD Foundation.

Martinsons Såg AB (2015). Envrionmental product declaration for glulam. Oslo: The Norwegian EPD Foundation.

Moelven Limtre as (2018). Environmental product declaraiton for project glulam. Oslo: The Norwegian EPD Foundation.

Moelven Töreboda (2016). Envrionmental product declaration for Glulam Beams and Pillars. Oslo: The Norwegian EPD Foundation.

Sørlaminering (2014). Environmental product declaration for standard glulam. Oslo: The Norwegian EPD Foundation.

STUDIES ON SELF-BONDING OF VENEERS WITH THE HELP OF AUTOMATED BONDING EVALUATION SYSTEM (ABES)

Authors: Jussi Ruponen*, Anti Rohumaa, Lauri Rautkari and Mark Hughes

About the corresponding (presenting) author:

JUSSI RUPONEN

DOCTORAL STUDENT

AALTO UNIVERSITY

JUSSI.RUPONEN@AALTO.FI; +358505608964

Co-authors:

Anti Rohumaa: project manager, Fiber Laboratory, South-Eastern Finland University of Applied Sciences, Savonlinna, Finland; Lauri Rautkari: assistant professor of Wood Material Science and Technology; Mark Hughes: professor of Wood Material Technology

Aalto University School of Chemical Engineering, Department of Bioproducts and Biosystems

MOTIVATION

Wood bonding with adhesives is a vast industry and business, and the market of wood adhesives was some 2 million tons in 2015 (Anon., 2015). The current main stream of wood adhesives is based on crude-oil derivatives, and due to, for instance, resource scarcity and environmental issues, there is and has been research focusing on non-fossil-resource-based wood bonding. According to several studies, it is possible to bond veneers with no external adhesives (Cristescu et al., 2006, 2015a & 2015b, Ruponen et al. 2014a & 2014b). The joint is frequently generated by employing wood constituents under elevated temperature and pressure. Regarding studies on self-bonding of veneers, several researchers have reported studies on lay-ups with many bond lines. However, there is not so much published information available on single bond line lay-ups. This paper presents a study, where an Automated Bonding Evaluation System (ABES) (Wescott et al. 2007) hot press was applied to join two veneers of rotary-cut birch (*Betula pendula,* Roth) with no external adhesives. The hot pressing parameters were varied and subsequent to conditioning, the tensile-shear strength tested.

EXPERIMENTAL

An Automated Bonding Evaluation System (ABES) hot press was applied to join two veneers of rotary-cut birch (*Betula pendula* Roth) with no external adhesives. The hot-pressing parameters were 220 °C and 5.0 MPa, while the press times were varied from 180 s to 600 s (60 s intervals). In addition to these, two log-soaking temperatures (20 °C and 70 °C) and two veneer initial moisture contents (MC) (6% and 11%) were applied to study the effect on the tensile-shear strength (TSS) of the joints. In general, the strength tests were run at 11% MC, but one set was partly duplicated and tested also at 6% MC, to observe the influence of the testing conditions, as well. To study the influence of the veneer surface properties, two sets of veneers were prepared for a comparison study where the one set was reference and the other set was altered by acetone extraction lasting for six hours.

RESULTS & DISCUSSION

According to the studies, the ABES device is suitable to be utilized in self-bonding of rotary-cut veneers and in testing these joints subsequently. Moreover, the bond lines represented substantial TSS values. In general, the TSS of self-bonded veneer joints correlated positively with the hot-pressing time. This is depicted in Figure 1 for all the tested five sets of veneers. The maximum TSS was 3.75 MPa (*AMM*) and the maximum average TSS 3.31 MPa (*ADM*), with an 8% proportional standard deviation. Both top values were observed for joints with 70°C log soaking temperature (*A*), with 11% MC testing condition (*M*) and with 600 s hot-pressing time. Despite the peaking TSS values with the higher log soaking temperature (*A*), the lower log soaking temperature, 20°C (*B*), resulted generally in somewhat greater average TSS and with a lesser proportional standard deviation. According to Rohumaa et al. (2014), phenol formaldehyde adhesive provided an average TSS of 5.3 to 6.1 MPa with similar veneers and with similar device. The partly duplicated set (*BDD*) lacks data from the longer hot-pressing times (480…600 s). Despite this deficiency, the results suggest that the joints conditioned to the lower testing MC (latter D, 6%) yield a higher TSS. Finally, the results signal that the lower initial MC (the prior *D*) leads to a stronger bond line, than that of the corresponding higher MC (the prior *M*).

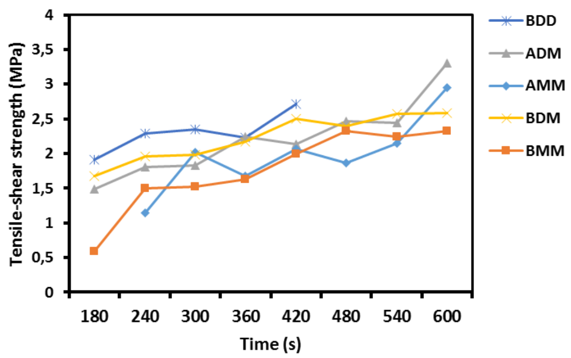


Figure 1. Tensile-shear strength as a function of hot-pressing time. B and A signify soaking temperatures 20°C and 70°C, respectively, whereas D and M signify MCs of 6% and 11%, respectively. The former D/M expresses the hot-pressing MC, whereas the latter D/M expresses the testing MC.

A double set of *BDD* veneers were prepared for a hot-pressing of 540 s. The log soaking temperature was therefore 20°C and both the initial veneer MC and the testing MC 6%. One set was hot pressed as the previous veneers and the other set was first acetone extracted. The TSS results from this comparison study are provided in Table 1.

Table 1. Tensile-shear strength results from the comparison study of extracted and unextracted BDD veneer with a hot-pressing time of 540 s.

Test	Unextracted veneers	Extracted veneers
Average (MPa)	3.39	2.85
St. dev. (MPa)	0.17	0.48
Proportional st. dev.	5%	17%

CONCLUSIONS

The maximum average tensile-shear strength (TSS) yielded 3.3 MPa (joints with 600 s hot pressing, conditioned to 6% MC prior hot pressing and 11% MC prior testing, from veneer with a log soaking temperature of 70°C). Generally, longer hot-pressing times, lower veneer initial MC and a lower testing MC led to greater TSS. Acetone extraction reduced the TSS and raised the standard deviation.

REFERENCES

Anon. (2015). *Wood Adhesives Market Analysis By Product (Urea-Formaldehyde, Melamine Urea, Phenol-Formaldehyde, Isocyanate, Polyurethane, PVA, Soy-based), By Application (Flooring, Furniture, Doors & Windows), And Segment Forecasts, 2018 – 2025*. San Francisco: Grand View Research, Inc, 145. Available at https://www.grandviewresearch.com/industry-analysis/wood-adhesives-market

Cristescu, C. (2006). Bonding of laminated veneers with heat and pressure only. In: *Proceedings of the 2nd international conference on environmentally compatible forest products "Ecowood"*. Porto. pp. 339-348.

Cristescu, C., Sandberg, D., Ekevad, M. and Karlsson, O. (2015). Influence of pressing parameters on mechanical and physical properties of self-bonded laminated beech boards. *Wood Material Science & Engineering*, 10(2), pp. 205-214.

Cristescu, C. (2015). *Self-bonding of beech veneers*. PhD. Luleå Technical University.

Rohumaa, A., Hunt, C.G., Frihart, C.R., Saranpää, P., Ohlmeyer, M. and Hughes, M. (2014). The influence of felling season and log-soaking temperature on the wetting and phenol formaldehyde adhesive bonding characteristics of birch veneer. *Holzforschung*, 68(8), pp. 965-970.

Ruponen, J., Rautkari, L., Belt, T. and Hughes, M. (2014). Factors influencing the properties of parallel laminated binderless bonded plywood manufactured from rotary-cut birch (*Betula pendula* L.). *International Wood Products Journal,* 5(1), pp. 11-17.

Ruponen, J., Ohlmeyer, M., Rautkari, L. and Hughes, M. (2014). Internal Vapour Pressure of Plywood During Hot Pressing Process. In: *Proceedings of the Seventh European Conference on Wood Modification ECWM7*. Lisbon.

Wescott J. M., Birkeland M. J., Traska A. E., Frihart C. R., Dally B. N. (2007). New Method for Rapid Testing of Bond Strength for Wood Adhesives. In: *Proceedings of the 30th Annual Meeting of The Adhesion Society, Inc.*, pp. 219-221.

NORDIC BUILDING CODES AND THEIR EFFECTS ON BUILDING OF RESIDENTIAL HOUSES FROM WOOD

Tomasz Noga*, Anuj Kumar and Erkki Verkasalo

Natural Resources Institute Finland (Luke), Yliopistokatu 6, 80100 Joensuu

TOMASZ NOGA

https://www.luke.fi/en/personnel/tomasz-noga/

TOMASZ.NOGA@LUKE.FI;+358 295322099

MOTIVATION

Growing urbanization provides new opportunities for building with wood and wood products value chains in residential, public, commercial and leisure building in Nordic countries. Multi-storey buildings with well-planned integration with built environment and transportation services as well public and house yard infrastructure built from wood, together with other materials, are currently in the focus of urban planning, but small-house areas continue to be important as well.

Harmonization of the EU standards aims to remove technical barriers to trade in the field of wooden construction and ensure the free movement of construction products across the EU. National standards and regulation policies set more specified requirements for buildings. Building codes set requirements but provide also opportunities for various business concepts, value chains and material choices for building with wood companies and wood products industries. It is recognized among Nordic countries that harmonization of building codes might be beneficial for promoting building with wood and creating new markets for wood products both from the perspective of public decision makers, builders and building companies as well as manufacturing industries in the supply chain.

In this paper we present first results on benchmarking of the building codes and concepts in Finland, Sweden and Norway that affect building with wood, with some implications to the opportunities for market development among supply chains of wood-based products and general promotion of building with wood.

EXPERIMENTAL

The research project was based on literature reviews, internet search and public statistics as well as semi-structured interviews among selected experts of building with wood, wood products industries, public decision making bodies and RTDI societies in Finland, Sweden and Norway. We chose personal interviews to get detailed and in-depth information about the experience and opinion of construction sector actors, instead of more general data from a larger group of respondents. We wanted to gain knowledge across the full value chain and stakeholders of the construction sector as well as from different levels within corporate hierarchy.

Prior to the actual benchmarking we defined the areas and items of building codes and regulations that may affect the market position of building with wood in multi-storey houses in particular and the opportunities of wood products industries to answer to the needs and requirements of building with wood. We also had to define the following terms for the purpose of the work: 1) Harmonization of building codes for wooden structures, 2) Standardization of design requirements for buildings of wood.

We analyzed the between-country differences in the respective codes and regulations and their effects on the volume and focus of the actual building with wood.

Based on the analysis, we will identify the clear bottlenecks and chances of the codes and regulations from the viewpoint of building with wood in each country. We present some building with wood practices and demonstrations and explore how the building codes and regulations have supported or not supported developing and increasing building with wood. Our final aim is to evaluate the needs and opportunities for Nordic harmonization in the building codes, regulation and their applications, considering the European regulatory systems.

RESULTS & DISCUSSION

Essential building codes and regulations

Buildings are designed to last for a long time, and partly because of this goal, construction companies are hesitant to try new things because they might result in unforeseen challenges (Levander 2010). The construction industry prefers to let someone else try new methods of construction, for example, multi-storey timber frames (Roos et al. 2010). Building codes designed and confirmed by public decision makers and technical and economical requirements set by builders and construction companies are in the core for the outcome of this potential.

Building codes focus on safety and health, such as structural safety, fire safety and acoustics requirements in buildings, indoor air, health effevts and well-being items as well as durability against decay, discoloration, molds, mildews and weather (moisture, UV radiation). In addition, energy efficiency (thermal insulation and heat and moisture buffering capacity related to indoor heating and air ventilation) and life cycle items (carbon storage, climate change) seem to grow in importance for building with wood.

Building codes and regulations in Finland, Sweden and Norway

Nordic building codes were shortly explored in the European collaborative research projects Wood2New (H2020) (Wood2New 2017) and the WoodWisdom-Net (WoodWisdom-Net 2015) research project FireInTimber. In these studies little could be concluded on the current situation for the building with wood markets. Most important, the harmonized EU building codes and regulations are the key standards, but they need to be developed and still harmonized.

Building codes and regulations enhance the competition in the construction markets and are even perceived as indirectly supporting the use of wood in multistory buildings. This, however, seems to leave a false impression. In contrast to that perception, it may be asked why and how regulation changes indirectly support a construction material, if no material restrictions are given, i.e. neither steel, concrete or other materials are banned. Instead, the growing usage of wood in construction can rather be ascribed to its suitability or problem solving ability in various aspects, e.g. prefabrication or environmental friendliness. In opposition to the perceived indirect support for wood, it could be stated that all other construction materials have been supported earlier, since wood was ruled-out from multistory constructions by placing material-related constraints instead of functional requirements in building regulations. Referring back to an enhanced competition on the construction markets, it has however to be stated that the markets for wooden multistory houses are developing relatively slowly but on the other hand due to the engineered material especially CLT and LVL speed up the building with wood market.

Fig. 1 shows general comparison among Nordic countries in forest culture and wood based housing and their current status and requirements. Nordic countries have a long tradition to build house with wood. Flooring and log houses are very common in Finland; Sweden and Norway used more joinery furniture and flooring. The future of high-rise building with wood depends mostly on the development of innovative engineered wood systems such as CLT, LVL etc.. On the other hand harmonization of building codes for wooden buildings is very essential for accelerating progress in construction sector.

Country	Forests culture in 2016	Forest coverage	Culture and heritage 200 years	Requirements and limitations	Key opportunity	Present use and future trends for wood use in interiors	Key innovations & technologies
Finland	Strong	72%	Flooring Walls (vernacular log houses)	Humidity Acoustic Insulation Maintenance	Health & Wellbeing Environmental credentials	Flooring Fit-out Joinery Growing trend:Multi-storey housing	CLT Advanced education programmes for wood technologies
Norway	Strong	38%	Flooring Walling Fit-out Joinery Furniture	Humidity Maintenance	Health & Wellbeing Environmental credentials	Flooring Walling Joinery Furniture	CLT
Sweden	Strong	70%	Flooring Fit-out Joinery Furniture	Humidity Maintenance	Environmental credentials Need for more housing	Flooring Fit-out Joinery Furniture	Easy-to-assemble interior solutions

Figure 1: Demonstrate of the comparison between three Nordic counties in term of forest status and culture of building with wood and requirements.

CONCLUSIONS

Our intention is to identify the most important opportunities and barriers to increase timber construction in Nordic countries from the regulatory point of view. The actual point is to find ways in building with wood to compete with the established solutions while bridging bio-economy and construction. Building codes and regulations will obviously develop in the future to common standards and dimensions as the basis for business concepts in Nordic countries, and create larger business opportunities for the green industries. This requires solid research basis to convince public authorities and business enterprises involved. The codes enacted and interpreted by the authorities constitute a major obstacle to competitive export. However, the construction industry works under the rules of market economy, hence, official codes should not distort the competition between different construction materials.

REFERENCES

Levander, E., 2010. *Addressing client uncertainty: a Swedish property owners' perspective on industrialised timber framed housing and property* (Doctoral dissertation, Luleå tekniska universitet).

Roos, A., Woxblom, L. and McCluskey, D., 2010. The influence of architects and structural engineers on timber in construction–perceptions and roles. *Silva Fennica*, *44*(5), pp.871-884.

Wood2New (2017) http://www.wood2new.org/wp-content/uploads/2017/02/2017-Wood2New-final-report.pdf

WoodWisdom-Net (2015) http:// www.woodwisdom.net/ wp-content / uploads / 2015/01/ acuwood_final_report.pdf

CURRENT STATUS AND FUTURE IMPLICATIONS OF FINNISH WOOD-BASED-PANEL INDUSTRIES

Anuj Kumar* and Erkki Verkasalo

Natural Resources Institute Finland (Luke), Yliopistokatu 6, 80100 Joensuu

ANUJ KUMAR

https://www.luke.fi/en/personnel/anuj-kumar/

ANUJ.KUMAR@LUKE.FI ; +358 295322088

MOTIVATION

Wood processing industries have long been the strength of Finnish economy. Among them wood-based panel industry (WBP) has concentrated on birch plywood since early 1900's and on softwood plywood and laminated veneer lumber (LVL) since 1990's, being currently market leaders in Europe. Instead, the position and size of chipboard (particleboard) and fibreboard industries has declined since 1980's owing to the lack of price competitiveness in export markets, limited domestic markets and strong import and stagnating investments and RTDI activity. Their raw material basis is nowadays solely in by-products of saw and plywood mills, such as saw dust, planer shavings, grinding dust, residual wood chips and bark, instead of more expensive small-diameter thinning woods and less used hardwoods during 1960's to 1980's (BS 2017). Recently, oversupply of the side streams of saw and plywood mills and other woodworking industries has lowered considerably the raw material price of WBP mills and calls for new markets and uses for these by-products. In parallel, continuous growth and more versatility in the European WBP markets, advanced technology development among machine and chemical manufacturers, specific product segments including engineered panel products and green building with lifecycle approach may provide potential for renaissance of Finnish WBP industry.

The main purpose of this paper is to review the current status and evaluate the future potential of Finnish wood based panel industries. The analysis includes historical prospects, current scope and structure, raw material and product trends, mill operations, fabrication lines and adhesives systems. One part of the work is to evaluate the challenges faced and opportunities found for the development of Finnish WBP industries.

EXPERIMENTAL

The research was carried out through literature and internet survey and data collection from Finnish Forest Industries, Wood Products Finland etc. and personal communication with wood based panel industries, machine manufacturers, adhesive producers and related RTDI experts. The work was focused to flake-based and fibre-based panel industries with short implications to veneer-based panel industries only.

CONCLUSIONS

The manufacture of wood products has long traditions. The choice of products is extensive, from sawn timber to engineered products, interior design products and furniture from top-class designers. Finland is a pioneer of the forest based bio economy, and produces a wide range of sustainable solutions for wood and wood products. On the other hand WBP industry is not moving forward in the similar direction like other wood products industries. There are only two WBP mills active in Finland, one is particleboard mill and second is fibreboard mill. Both are using the old traditional production lines without upgrading them with the latest state of art technology. During this decade the price of raw materials has come down in Finland despite the increased demand for energy sector. Plenty of sustainable side stream and roundwood raw materials are still available for the future.

REFERENCES

Berthold, D., Meinlschmidt, P. and Ritter, N. 2017. Hardwood processing in Europe – Challenges and opportunities for the wood based panel industry. In: Möttönen, V. & Heinonen, E. (Eds.). ISCHP 2017: 6th International Scientific Conference on Hardwood Processing – Proceedings. Natural Resources and

Bioeconomy Studies (BS) 80/2017. Pp. 97-108. Natural Resources Institute Finland (Luke). https://jukuri.luke.fi/handle/10024/541001

FAO, 2017. *Global Forest products fact and figures, 2016.* FAO, 2017 I7034EN/1/12.17. Rome, Italy: Food and Agriculture Organization of the United Nations.

Finnish Forest Industries (FFI), 2018 [06/17, 2018]. https://www.forestindustries.fi/statistics/

Kumar, A., Staněk, K., Ryparová, P., Hajek, P. and Tywoniak, J., 2016. Hydrophobic treatment of wood fibrous thermal insulator by octadecyltrichlorosilane and its influence on hygric properties and resistance against moulds. *Composites Part B: Engineering*, *106*, pp.285-293.

Hemmilä, V., Adamopoulos, S., Karlsson, O. and Kumar, A., 2017. Development of sustainable bio-adhesives for engineered wood panels–A Review. *RSC Advances*, *7*(61), pp.38604-38630.

Varis, R. (Ed.). 2018. Wood-Based Panel Industry. Finnish Woodworking Engineers Association. Bookwell Oy, Porvoo, Finland. 276 p.

ANALYSIS OF A 17TH CENTURY HISTORICAL ROOF TIMBER SYSTEM IN THE OLD TOWN OF BERLIN-SPANDAU

Authors: Matthias Lüke and Wibke Unger and Dieter Nellessen

MOTIVATION

In Europe the "Charta of Venedig" was enacted 31st May 1964. This is the international directive for the preservation of historic buildings and monuments. All countries in Northern Europe wish to involve professional wood scientists and engineers in maintaining and preserving historical buildings. Here we discuss a restoration project involving 17th century roof timbering. This project may be used as a model applicable to many other wooden historical monuments.

EXPERIMENTAL

Characterization of the Tradesman House

The Tradesman House was built approximately 1686. Figure 1 shows Berlin-Spandau in 1728.

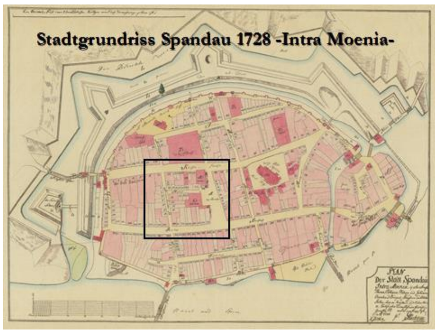


Figure 1: Ground plan Berlin-Spandau of 1728

The house is a typical plain wooden frame structure. The storefront is in the baroque style. The address of the house is Charlotten Street 10.

Basic physical construction

The roof timbering consists of 9 roof truss containers, each described and plotted. The technical drawings are in the Diploma of Matthias Lüke. These identified all typical biotic and structural damages. The illustrations show measurements for moisture content, relative humidity and temperature. In addition, measures for the reconditioning of the historical roof timbering are explained.

RESULTS & DISCUSSION

Report of the original construction

The historical roof timbering is a collar beam roof, seen in Figure 2. These wooden constructions are a rarity in Berlin-Spandau. This system was used mainly until the end of the war (1618-1648) in the 17th century. The different wooden timbers were fashioned and assembled by hand.

The roof timbers within the walls were constructed to allow packing with straw and loam (Figure 2).

Figure 2: Left – Collar Beam Roof. Right –Wooden Stakes filling by Loam and Straw

Identification of the wood used in the historical roof timbering

To determine the wood species the probe was taken from the number 8/ 21 in the attachment II of the Diploma Thesis of Matthias Lüke. The wood is Scots Pine (*Pinus sylvestris* L.). It was common to use Scots Pine for roof timbering in the area close to Berlin.

Measurement of moisture content, relative humidity and temperature in the building

During the study the moisture contents of the wood parts varied between 13.7 % and 32.4 %. The recorded temperature was 12.8 °C and the relative humidity 69.2 %.

Report about the scarcity value

The results of numerous inspections confirmed an invasion by wood destroying insects and fungi. Damage was recognized as caused primarily by:

House Longhorn Beetle (*Hylotrupes bajulus* L.)
Common Furniture Beetle (*Anobium punctatum* De Geer)
The Dry Rot Fungus (*Serpula lacrymans* Wulfen: Fr.) Schroeter).

In the wooden rafter sections of the historical roof timbering, damage caused by the House Longhorn Beetle and the Common Furniture Beetle was especially recognizable (Figure 3). The infestation caused by the insect *Hylotrupes bajulus* was no longer observed to be active.

Figure 3: Left - Damage by *Hylotrupes bajulus.* Right - Sawdust of *Anobium punctatum*

We were excited to find mycelium of the Dry Rot Fungus in the eaves area of the roof, as seen in Figure 4. Wood decay was especially notable at the heading sections of the beams.

Figure 4: Left - Mycelium of the Dry Rot Fungus. Right –Brown Rot at the heading section of the beams

Mapping of the damages

All details in the report about the scarcity values were plotted by computer-aided planning. One example is seen in Figure 5. The figure shows the gable roof number 9; left side is the Charlotten Street 10; right side is the garden. The status analysis of the damages is the substructure of the reconditioning.

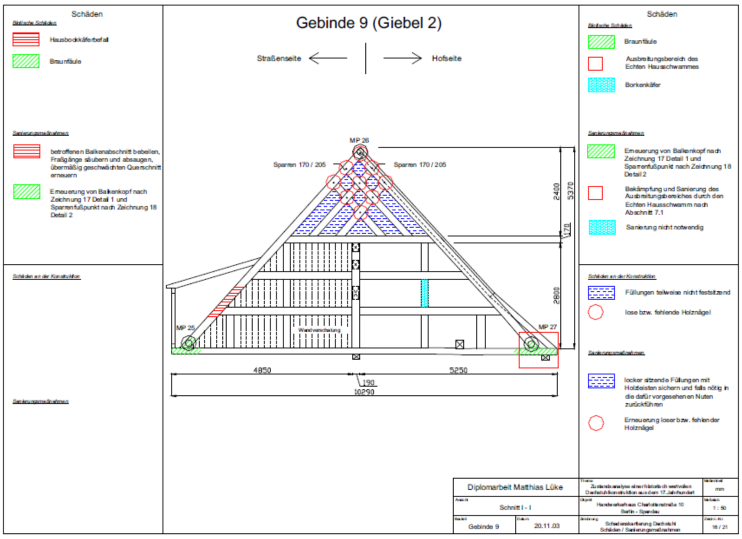


Figure 5: Gable roof number 9. First are signed the scarcity values. Secondly are signed advices for reconditioning. (In German)

CONCLUSIONS

The analysis of a 17th century historical roof timber system in the old town of Berlin-Spandau is a reference for preservations of historical buildings and monuments. Also it is a reference of functions and basic principles for the reconditioning. The first task of the reconditioning is to remove the reasons of biological damages. The principle of the reconditioning procedure is to maintain the inventory monument in grain and to show the building sites of the historic meaning.

REFERENCES

Charta von Venedig_30-05-2015-0620.4 mp3

Putz, Jens and Unger, Wibke (2012). Research report and inventory valuation of the Goeritz Manor House (Brandenburg) before its termination. *IUFRO – the International Union of Forest Research Organizations* - IUFRO World Congress Lisbon 2012 – IUFRO All-Division 5 Conference: 08. - 13.07.2012.

Ridout, Brian (2000). *Timber Decay in Buildings. The conservation approach to treatment*. London and New York: SPON PRESS. p. 232.

Schmidt, Olaf (2006). Wood and Tree Fungi. Biology, Damage, Protection, and Use. Berlin Heidelberg: Springer-Verlag. p. 334.
Schulze, Axel and Unger, Wibke (2011). Cobblestone Church in Gross Gievitz: Historic Wooden Construction and Potential for Conservation and Use. *The International Research Group on Wood Protection.* IRG/WP 11-10760. p. 12.
Unger, Achim, Schniewind, Arno P. and Unger, Wibke (2001). *Conservation of Wood Artifacts. A Handbook.* Berlin and Heidelberg and New York: Springer-Verlag. p. 578.