COST FP1303 Meeting

Design, Application and Aesthetics of biobased building materials

Vitosha Park Hotel, Sofia, Bulgaria

28 February – 1 March 2017

Agenda

TUESDAY 28th February, 2017		
08:30 – 08:45		Welcome, Introduction
08:45 – 09:15	1	Peter Wilson Building the New World: Innovation and Paradigms in Bio-Based Architecture
09:15 – 09:45	2	Emilia Markström Prospects for an Increased Use of Bio-based Building Materials in Sweden
09:45 – 10:00	3	David Lorenzo Performance of fir timber houses built in Northern Spain. The examples of wooden buildings and the importance of design details in the performance.
10:00 – 10:15	4	Mohammed Hussein Hoballah Discovering design principles of a wood-based insulating material through multi-objective optimization
10:15 – 10:30	5	Simon Curling Implications of synergistic durability relationships on design of construction elements
10:30 – 11:00		**COFFEE**
11:00 – 11:15	6	Thomas Thiis Simulation of weathered colour change on an untreated aspen façade
11:15 – 11:30	7	Jöran Jermer Performance of a noise barrier with different wood materials – results from a service trial after 20 years' exposure
11:30 – 11:45	8	Julia Buchner How do biotic and abiotic factors combine to affect the weathering of wood surfaces?
11:45 – 12:00	9	Ingunn Burud Comparing hyperspectral imaging technology and visual assessment for mould growth on wooden surfaces
12:00 – 12:15	10	Zuzana Vidholdova Colour changes of wooden shingles treated with pine tar after weathering
12:15 – 12:30	11	Athanasios Dimitriou Surface characterisation of spruce to understand the effects of natural weathering
12:30 – 13:30		**LUNCH**
13:30 – 13:45	12	Bostjan Lesar COST FP 1303 Cooperative Performance Test – Results after 2 years outdoor exposure
13:35 – 14:00	13	Linda Meyer-Veltrup Durability-based design of timber structures – Quantifying design, exposure, and resistance on the basis of dose-response relationships
14:00 – 14:15	14	Cihat Tascioglu Seventh-year durability analysis of post-treated wood-based composites
14:15 – 14:30	15	Jakub Sandak Development of an algorithm for computation of the weather dose used for natural weathering models
14:30 – 14:45	16	Liselotte DeLigne Fungal susceptibility testing of bio-based building materials: using image analysis as an assessment tool
14:45– 15:18		**POSTER SESSION**

14:45 – 14:48	17	Aneta Gumowska Sorption hysteresis of selected structural wood – based composites
14:48 – 14:51	18	Emilia Salca Some aesthetic decorative features of varnished surfaces
14:51 – 14:54	19	Morwenna Spear Artificial weathering effects on glue bond, varnish stability and surface appearance in thermally modified larch
14:54 – 14:57	20	Younes Aounes Updating the Reliability of cracked timber structures by using experimental results and numerical fracture model
14:57 – 15:00	21	Izabela Burawska Research on modified floorboard of higher hardness
15:00 – 15:03	22	Vjekoslav Živković Contribution of Site Orientation to the Seasonal Fluctuations of Wood Moisture Content in Wooden Windows
15:03 – 15:06	24	Miklos Bak Colour variation within the material of new Robinia varieties with high growing rates
15:06 – 15:09	25	Anna Rozanska Possibilities to Use Modern Biobased Materials in Traditional Wooden Beam Floors
15:09 – 15:12	26	Kristine Nore Passive conditioning with wood in grocery stores
15:12 – 15:15	27	Simon Curling MDF Recovery: Recycled MDF technologies for routed and laminated applications.
15:15 – 15:20	49	Andreja Kutnar Introduction to the InnoRenew project
15:15 – 16:00		**COFFEE AND POSTERS**
16:00 – 16:15	28	Wibke Unge Durability testing of a cattail (Typha spp.) based insulation material against termite attack
16:15 – 16:30	29	Younes Aoues Time-variant Reliability of a timber truss subjected to decay considering humidity and temperature climate change
16:30 – 16:45	30	Rostand Moutou-Pitti Environmental impact on crack propagation of biobased building materials: application to Abies Alba Mil
16:45 – 17:00	31	Lothar Clauder Emissions from bio-based building products
17:00 – 17:15	32	Katja Vahtakari Functional properties of wooden surfaces in real indoor environments
17:15 – 17:30	33	Charalampos Lykidis The use of NIR spectroscopy as a quality marker of hydrothermally treated wood
17:30 – 17:45	34	Marko Povacvesic Bringing nature into workspaces: Employees’ perceptions of their offices
17:45 – 18:00	35	Morwenna Spear Combining the science and design of plant cells and structures
18:00		**CLOSE OF DAY**

WEDNESDAY 1ST MARCH, 2017		
08:45 – 09:00	36	Miha Humar Susceptibility of the conifer wood toward blue staining
09:00 – 09:15	37	Roman Reh Aesthetics of composites with the surface decorative veneers made of silver maple (Acer saccharinum L.)
09:15 – 09:30	38	Mark Irle The Internal Structure of Modern Wood and Plastic Fibre Insulation Materials
09:30 – 09:45	39	Rene Herrera Diaz Potential use of plant extracts for protection of wood veneers
09:45 – 10:00	40	Cesar Niyigena Evidence of low impact of hemp bio-aggregates on the thermal conductivity of hemp concrete
10:00 – 10:30		**COFFEE**
10:30 – 10:45	41	Susanna Kallböm Water vapour sorption characteristics of thermally modified Norway spruce particles
10:45 – 11:00	42	Mladjan Popovic The curing behaviour of urea-formaldehyde adhesive in the presence of chemically treated narrow-leaved ash (Fraxinus angustifolia Vahl. ssp. Pannonica Soo & Simon)
11:00 – 11:15	43	Charlotte Grosse Modifying wood with poly(butylene succinate). Influence of humidity on oligomers diffusion into the wood cell walls by screening of heat treatment parameters
11:15 – 11:30	44	Miklos Bak Decreasing the hygroscopicity of wood with nanoparticles
11:30 – 11:45	45	Tonis Teppand Using reinforced GLT laths for constructing grid shells without supports
11:45 – 12:00	46	Marius Aleinikovics Analysis of HWP production and impact on carbon storage in Lithuania
12:00 – 12:15	47	Mario Marra Design of Wood Wool Cement Board by Life Cycle Assessment method
12:15 – 12:30	48	Eduardo Robles Modified cellulose nanofibers thin-film as external layer for wood-based multi-layer composites
12:30		**CLOSE OF MEETING, LUNCH**
13:30		**MANAGEMENT COMMITTEE MEETING**

Preface

The building sector is strongly requested to provide reliable data on the performance of building materials and products, in particular for highly demanded renewable materials from sustainably managed production. In this respect bio-based products can play a key role and enormous efforts have been made to study and classify a wide range of materials in a quantitative manner. Mechanical, physical, thermal and acoustic properties as well as durability against different biotic and abiotic agents are well investigated as it was focussed by material scientists for decades. However, material characteristics need to get interpreted dependent on the respective in-use conditions. The performance of organic and thus biodegradable materials is affected by climatic parameters, in particular the microclimatic and material-climatic conditions, which are in turn affected by the global climate and design of the respective applications. Performance prediction of structures and components made from bio-based building materials therefore requires particular tools and instruments allowing for consideration of both, material resistance and exposure. For many applications, the key performance criteria are not stability or functionality; it is simply the optical appearance or human well-being that decides on their serviceability. Nevertheless, also aesthetics and comfort are affected by climate, design and the respective in-use conditions.

More recently, several research activities were started and/or intensified in Europe and beyond to further dig into the cross-links between material science, design, architecture, engineering, and social sciences. This workshop will therefore focus on 'Design, Application and Aesthetics of Bio-Based Building Materials'. On the one hand, many contributions have been made to highlight the need for multidisciplinarity in this field of research. On the other hand, valuable examples are presented for exploring the parallelism of performance mechanisms and protective modes of action with respect to different bio-based building materials. Design principles will be presented and critically discussed with respect to the various definitions of performance, different bio-based materials, and different user groups.

On behalf of COST FP 1303 I wish you a successful workshop in Sofia with many interesting presentations, fruitful discussions, and many opportunities for networking!

Christian Brischke

Vice-Chair COST Action FP 1303

ABSTRACTS

Building the New World: Innovation & Paradigms in Bio-Based Architecture

Peter Wilson[1]

[1] Timber Design Initiatives Ltd, 90a Constitution Street, Edinburgh EH6 6RP

pw@timberdesigninitiatives.eu

Keywords: Architecture, Bio-based, Construction, innovation, Offsite

Europe has been in the vanguard of new product and technological development in the world of wood for the past 30 years and, with innovative timber solutions continuing to experience exponential market growth as a consequence of the changing environmental sensibilities that seek low- or zero-carbon alternatives to traditional modes of construction. The doorway to explore, research, develop, test and demonstrate new and highly innovative bio-based ideas has never been more open than it is today.

Through this open door have stepped some of the world's most creative architects and engineers, academics and researchers, scientists and building technologists, manufacturers and building contractors who, working in collaboration or in parallel, have sought to discover new approaches and opportunities to use traditional bio-based materials or to re-think and adapt their properties in order to develop products and construction systems not previously available but which offer positive solutions to contemporary environmental challenges and societal imperatives. From this cauldron of experimentation, the beginnings of a new, and arguably more humane, architecture has begun to emerge, offering paradigms for a range of building types for which few precedents exist.

By contrast with previous phases of architectural development, this new design approach - whilst drawing on varying strands of construction evolution - is still in the main ungrounded in any particular philosophy, theory or style, shaping itself instead around a growing understanding of the properties of bio-based materials and the varying building types their application is being considered for.

The results to date are intriguing: whether used individually or in combination, this rethinking of bio-based materials is delivering a very different approach to design and construction and with it a very different form and look to the structures we require today - *ipso facto* we are witnessing the gestation of a new architectural aesthetic. In this evolving context, old technologies are also being re-invented: the prefabrication of thatch panels, for example, takes a traditional skill out of the seasonal cycle into the world of controlled factory conditions, enabling year-round employment for craftsmen whose ability to work was previously completely weather-dependent. In such an example, the transfer to offsite manufacturing facilities and the introduction of Modern Methods of Construction (MMC) are bringing efficiencies and greater precision to the process which make the use of locally produced materials possible once again, thereby stabilising the existence of small, craft and bio-based industries and helping to sustain the cultural and economic vitality of often remote rural areas.

This new industrialisation of craft-based skills, in combination with scientific and technical development of the bio-based materials employed, also requires evolution in the ways we measure their capability, enhancement, functionality and performance. Taking each of these criteria forward in order to establish new standards for bio-based materials can lead to wider, mainstream - and potentially global - applications for bio-based materials and technologies in architecture and construction.

References:

Wilson P., August 2016. IOM Communications Ltd., London. Materials World Volume 24 Number 8, 28-32

Prospects for an Increased Use of Bio-based Building Materials in Sweden

Emilia Markström[1], Anders Bystedt[2], Dick Sandberg[3]

[1] Forskargatan 1, 931 87 Skellefteå, Sweden, Luleå University of Technology, emilia.markstrom@ltu.se
[2] Laboratoriegränd 2, 931 62 Skellefteå, Sweden, RISE Research Institutes of Sweden, anders.bystedt@rise.se
[3] Forskargatan 1, 931 87 Skellefteå, Sweden, Luleå University of Technology, dick.sandberg@ltu.se

Keywords: construction industry, stakeholder perception, drivers and barriers

Introduction

In Europe, the building sector accounts for 40% of the greenhouse gas emissions. To limit the climate impact of buildings, low carbon materials such as bio-based materials could be used. Architects, contractors, and developers are key-decision makers for the selection of materials in the construction sector, and how they perceive bio-based materials is therefore of high importance for the replacement of fossil-based materials with low carbon materials.

The present study is intended to contribute to the understanding of the probability that bio-based materials are chosen in residential buildings and to the understanding of drivers and barriers for an increased use of bio-based building materials.

Method

The methodological approach rests on the Theory of Planned Behaviour (TPB) (Ajzen 1985) - which in short states that a person's intention to behave in a certain way together with the perceived ability to perform the behaviour can be used to describe expected behaviour - and on Innovation Theories (Rogers 2003). A qualitative approach with semi-structured interviews was used. In total, 12 interviews were held with Swedish architects, contractors and developers. The study targeted larger firms and also aimed at a geographical spread. More detailed information about the study can be found in Markström et al. (2016).

Results and discussion

A person's intention to behave in a certain way is dependent on that person's attitude towards the behaviour and what important others think about it (the subjective norm) (Ajzen 1985). The architects had a positive attitude to bio-based materials in general and appreciated that wood is a living material that gives warmth to a building. The contractors' attitudes to bio-based materials were in general somewhat negative, even though there were indications that these attitudes slowly are staring to change in a positive direction. In general, the developers saw some positive aspects with using bio-based materials but the perceived negative aspects connected to the use seems to weigh more at the moment. When it comes to the subjective norm, the answers were quite similar between the three groups of actors. The construction sector was described as conservative and risk averse. The respondents experienced that negative attitudes to bio-based materials existed within the sector but that the interest in these materials seems to be growing.

A lack of knowledge and experience of bio-based materials was identified among all the actors. These aspects have earlier been shown to influence the expected behaviour to a large extent (Bysheim and Nyrud 2009). Further, the contractors and developers perceived greater possibilities to influence the material selections than the architects.

Drivers and barriers for selecting bio-based materials identified are presented in Table 1.

Table 1: Identified drivers and barriers

Barriers		**Drivers**
- New and not tested - Tradition in building with concrete - Bad examples - Lack of knowledge - Too costly - Maintenance - To short service-life - Mould and moisture damage	- Fire safety - Acoustics - Cracks and settlements - Hard to obtain an airtight structure - Shortage of construction workers - Local plan - Insurance issues	- Faster construction - Social benefits - Green building certification - Political pressure to decrease environmental impact - Lack of labour in lager cities → work is relocated → prefab. is convenient

Conclusions

The results indicate that the probability of selection of bio-based material among the group of respondents is low. The major barriers for selecting bio-based materials identified are related to culture and habits within the construction sector and to material properties. Key drivers identified are related to environmental performance of the materials.

References

Ajzen, I. 1985. From Intentions to Actions: A Theory of Planned Behaviour. In: Kuhl, J. and Beckmann, J. (Eds.). Action control. Springer-Verlag, Berlin Heidelberg, Germany. pp. 11-36.

Bysheim, K., Nyrud, A.Q. 2009. Using a predictive model to analyse architects' intentions of using wood in urban construction. Forest Products Journal, 59(7/8):65-74.

Markström E, Bystedt A, Fredriksson M, Sandberg D. 2016. Drivers and barriers for an increased use of bio-based building materials in Sweden. In: Wood science and engineering – a key factor on the transition to Bioeconomy. Proceedings of the 12th meeting of the Northern European Network for Wood Science and Engineering (WSE). pp 15-21.

Rogers, E.M. 2003. Diffusion of Innovations. Free press, New York.

Acknowledgments: Financial support from the Swedish Research Council Formas (Project EnWoBio, 2014-172) and RISE Research Institutes of Sweden (former SP Swedish Technical Research Institute) is gratefully acknowledged.

Performance of fir timber houses built in Northern Spain. The examples of wooden buildings and the importance of design details in the performance.

David Lorenzo[1], Josu Benito[2], Juan Fernández-Golfín[3], Manuel Touza[4], Manuel Guaita[2], Alfonso Lozano[5],

[1] Engineering for Rural and Civil Development. University of Santiago de Compostela, 27002 Campus s/n Lugo, Spain, davidlorenzofouz@gmail.com

[2] TECNALIA R&I, Área Anardi 5, 20730 Azpeitia Guipuzcoa, Spain, josu.benito@tecnalia.com

[3] Forest Research Centre (CIFOR) National Institute for agricultural and Food Research and Technology (INIA), 28080 Madrid, Spain, golfin@inia.es

[4] GAIN CIS-Madeira, Galicia Technological Park, 32901 San Cibrao das Viñas, Ourense, Spain, manuel.cesareo.touza.vazquez@xunta.es

[5] Construction Engineering Area, EPS, Edificio Oeste nº 7, Campus de Gijón E-33203 Gijón, Spain, alozano@uniovi.es

Keywords: Use class, wood, performance, decay, aesthetics, design, buildings.

Designers working with wood in Spain don´t have reliable tools and methodologies which allow to properly assessing the functional performance and service life of wood in exterior constructions, depending on the local weather conditions and also on the adopted design and inherent wood material variables. The existence of Guidance documents developed in Northern Europe does not solve the problem in Spain, due the encountered very different climates, wood species and constructions system designs. There is a dose of degradation, performance and service life in exterior uses, inherent to each national geographical location (local climate) and depending on conditions of use of wood and details design as: sheltering, distance from ground, moisture traps, and exposition to wind-driven rain, coatings, physical protection, ventilation, maintenance, etc. In short, all these factors generate finally irreversible changes to the wood material due to biological and abiotic agents, to the material itself, and also to climate and design details.

The paper presents the main pathological processes that occur in houses in northern Spain built with timber elements. From last century the construction based in wood walls has back in Spain.

The reason is mainly due the improvements in glues, design by computer and processing in factories. All these technological advances have facilitated the development industrialized systems cheaper. However, this variety of row materials, designs and construction systems, combined with the different climates have as result pathological problems associated to wood destroying fungi, insects an aesthetics.

Independently of the problems about beetles attacks, that normally don´t provoke structural problems in the timber houses, the most important problems in the structural elements of these

constructions are the attacks of wood destroying fungi and in some cases the attacks of termites as well aesthetics. In some timber houses the damages are very important and have reduced the durability and security of some structural elements.

The examples of timber houses show degradations due wood decay in different parts depending on design details. In situ inspections considering the main factors have been conducted to assess the real wood degradation status of, focusing on: wood species resistance, local climatic conditions and influence of design details. It is important to analyze their ability to withstand degradation over time in order to identify the parameters influencing performance and service life. Harms range from simple aesthetic defects to serious problems affecting even the stability of the construction.

The wood specie selected for building the wood walls and the design details are fundamentals for the service life and durability. The wood walls degradation depends on firstly on the wood specie selected but also depends on driven rain and winds, design details, joints and maintenance. In other words, the correct identification of the use class is necessary not only to the façade or construction parts, is also fundamental in the joints.

Figure 1: *Fir* wooden house located in Northern Spain.

References

EN 335 (2013) “Durability of wood and wood based products. Use classes: definitions, application to solid wood and wood-based products”.

EN 350-2 (1994) "Durability of wood and wood-based products - Natural durability of wood - Part 2: Guide to natural durability and treatability of selected wood species of importance in Europe".

EN 460 (1995) "Durability of wood and wood-based products- Guide to the durability requirements for wood".

Discovering design principles of a wood-based insulating material through multi-objective optimization

HOBBALLAH Mohamad Hussein[1], MICHAUD Franck[2], NDIAYE Amadou[3], IRLE Mark[4]

[1] 351 Cours de la Libération Talence, France, Lunam university Ecole supérieure du bois LIMBHA, mohamadhussein.hobballah@ecoledubois.fr

[2] 7 Rue Christian Pauc Nantes, France, Lunam university Ecole supérieure du bois LIMBHA, franck.michaud@ecoledubois.fr

[3] 351 Cours de la Libération Talence, France, Inra Bordeaux, amadou.ndiaye@inra.fr

[4] 7 Rue Christian Pauc Nantes, France, Lunam university Ecole supérieure du bois LIMBHA, mark.irle@ecoledubois.fr

Keywords: Multi-objective optimization, Composite, Wood fibres, Insulation.

Abstract

Meta-heuristic approaches provide efficient methods for the optimization of conflicting design objectives. Multi-objective particle swarm optimization algorithm (MOPSO) has been used here to extract useful design principles in the context of developing an insulating material based on wood fibers. First, objective functions of thermal conductivity and thickness recovery were modelled using experimental data and expertise of experts. Then, MOPSO algorithm was applied to calculate the set of Pareto-optimal solutions (Fig.1). Finally, this set was analysed to extract useful design principles. Examples of design principles extracted from the Pareto front are: High percentage of optimal solutions has a fineness value between 100 and 200 μm, then mixed raw materials to be considered. 3 % of solutions has a fineness value between 300 and 350 μm, then this interval of fineness is not optimal, such fineness may not be considered for insulation application. All optimal solutions have a density between 60 and 75 kg/m3, this interval is then considered as optimal regarding the optimization objectives. Any solution with a density outside of this range means that there is a loss in resources, and a better solution can be found, always according to Pareto optimality.

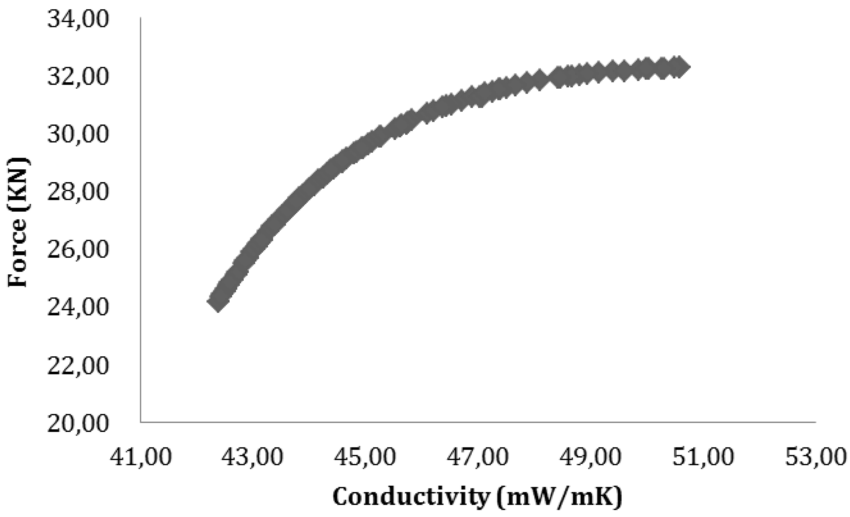


Figure 1: The set of Pareto-Optimal solutions

References

Deb, K., & Srinivasan, A. 2006. "Innovization: Innovating design principles through optimization." Proceedings of the 8th annual conference on Genetic and evolutionary computation.

Langlais, C & Klarsfeld, S., 2004. Isolation thermique à température ambiante - Bases physiques. Techniques de l'ingénieur, traité construction, BE6(BE9859):1-17

Reyes-Sierra, M., & Coello, C. C. 2006. Multi-objective particle swarm optimizers: A survey of the state-of the-art. International journal of computational intelligence research, 2(3): 287-308.

Tran, H., 2013. Study of Compression Behaviour of Wood-Based Fibreboard: Characterization using Non-destructive Images Technique. Phd Thesis.

Implications of synergistic durability relationships on design of construction elements.

Simon Curling[1], Graham Ormondroyd[2,3]

[1] BioComposites Centre, Bangor University, Bangor, Gwynedd, United Kingdom LL572UW. s.curling@bangor.ac.uk

[2] BioComposites Centre, Bangor University, Bangor, Gwynedd, United Kingdom LL572UW. g.ormondroyd@bangor.ac.uk

[3]Department of Architecture and Civil Engineering, University of Bath, Claverton Down, Bath, BA2 7AY, UK

Keywords: Modular Construction, biobased, synergy, durability

The use of preformed modular walling units is a construction approach that is seeing more abundant use and is becoming a widely available method. Preformed units are usually a composite structure which often include a range of bio-based materials such as timber, wool or straw. This construction method has a number of advantages such as speed and uniformity of the structure.

However, as with all biobased materials the risk of microbiological attack is ever present, and dealing with this risk must be an important part of the design of the modular elements. When looking at durability of biobased materials the standard approach has been to look at methods used for the most ubiquitous biobased material used – ie wood. There are a number of methods available for determining the durability of wood based materials to the action of decay fungi e.g EN 113. However, these may not always be the most appropriate tests for non-wood materials, although they will provide some information (Curling et al 2015).

One area that that traditional laboratory based tests do not take into account is the combination of biobased materials, as may be seen in modular constructions. It is possible that non-wood materials such as plant or animal fibre insulation may act as a moisture reservoir or moisture buffer for wooden structural elements with a consequential effect on their durability. This could be seen as a synergistic relationship between the materials.

This paper details an experimental approach to determine if there could be such an effect, using a modified form of existing wood decay testing methods. The test utilises an agar jar approach with a pad of fibrous insulation e.g. wool or hemp placed between the inoculated agar and a wood block.

Results show the effects of eh type of insulation used on the moisture content and decay of the test blocks. The test show that wool for example appeared to hold water away from the wood samples and reduced subsequent decay (Figure 1). Hemp however, did not prevent water access to the wood blocks and in fact enhanced decay of the blocks.

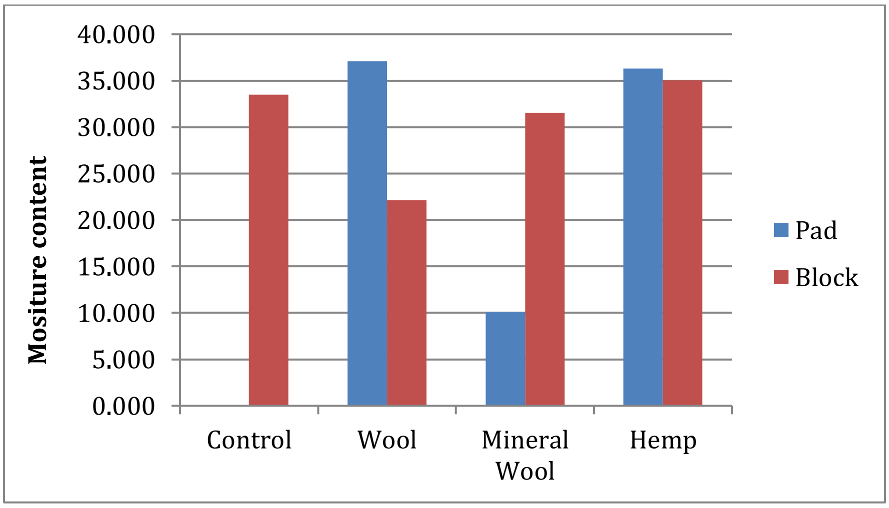


Figure 1 Moisture content of insulation pad and wood block following exposure to *Coniophora puteana*.

References

Curling S, F, Stefanowski B K, Mansour E, Ormondroyd G A (2015) Applicability of wood durability testing methods to bio-based building materials International Research Group on Wood Preservation Document IRG/WP/15-20561 Vina Del Mar, Chile, May 11th – 14th 2015

Acknowledgments:

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 609234

Simulation of weathered colour change on an untreated aspen façade

Thomas Thiis[1], Petter Stefansson[1], Stergiani Charisi[1], Ingunn Burud[1]

[1] Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology, Campus Ås, PO Box 5003, 1432 Ås, Norway, ingunn.burud@nmbu.no

Keywords: Weathering, Climate, façade, simulation

Building façades are exposed to a microclimate, which has a very high spatial variation. This leads to differences in degradation of the façade material, which, in turn, gives variation in colour. Since wood is a material which is quite susceptible to colour change, the phenomenon is often very apparent on untreated wooden facades. The use of untreated wood as façade material is increasingly popular in northern Europe. The reasons for this are multiple and includes sustainability issues as well as aesthetic considerations. However, even if there is substantial research on the topic, there are still issues in communicating how climatic exposure will change the appearance of a wooden façade. Both the tasks of communicating the chemical and physical phenomena to the architect (which should be the building physicist's responsibility), and the task of explaining how the expression of the building will be affected by the climate, which should be the architect's task are difficult. In a planning process, it is important to reduce the uncertainty in the building project. Knowledge of degradation of the façade material and development of the colour is therefore important. To improve the information flow of the parties in the building planning process, digital building information models (BIM) has become the new standard tool in the building industry.

This paper aims to demonstrate how 3D models can be used to present colour changes of the façade caused by variation in micro scale climate. The basis for the colour change is the climatic exposure of the façade. Since the colour change is sensitive to weather exposure, knowledge of micro scale weather is the key factor in simulating the colour change. Thiis et.al. (2016), have simulated microclimate on facades with the purpose of determining the façade material response to climatic exposure. In Thiis et.al. (2016) the micro scale weather exposure was coupled to the mould resistance design (MRD) model of Thelandersson & Isaksson (2013) in which the onset of mould growth can be predicted by combining relative humidity and temperature for any given climate. This model excludes solar radiation, which has proven to be vital to the colour change of wooden facades. However, the definition of the climatic dose from moisture and temperature has proven to give adequate results for mould growth.

Since mould growth will contribute significantly to the colour change of a façade, this climatic dose is combined with the solar radiation and adopted as the key climatic factors influencing the colour change of the untreated wooden facade in this paper. The models for color development are least squares regression models using the climatic doses as variables in three separate models for the CIE L, a and b dimensions. The models are time dependent allowing for simulation of temporal and spatial colour change on facades. The model is based on the façade of Ås High School, which has untreated aspen as material in the façade, Figure 1. The CIE L,a,b values are estimated from calibrated RGB photos in approximately 20.000 points. The hourly weather, which are used in the climatic doses, is simulated in all these points using the method described in Thiis et.al. (2016). The results of the colour simulation is shown in Figure 2. The simulation captures the general variation in colour. However, since wood is highly inhomogeneous, the visualization of the results does not look realistic at close range.

Figure 1. Study object, Ås High School

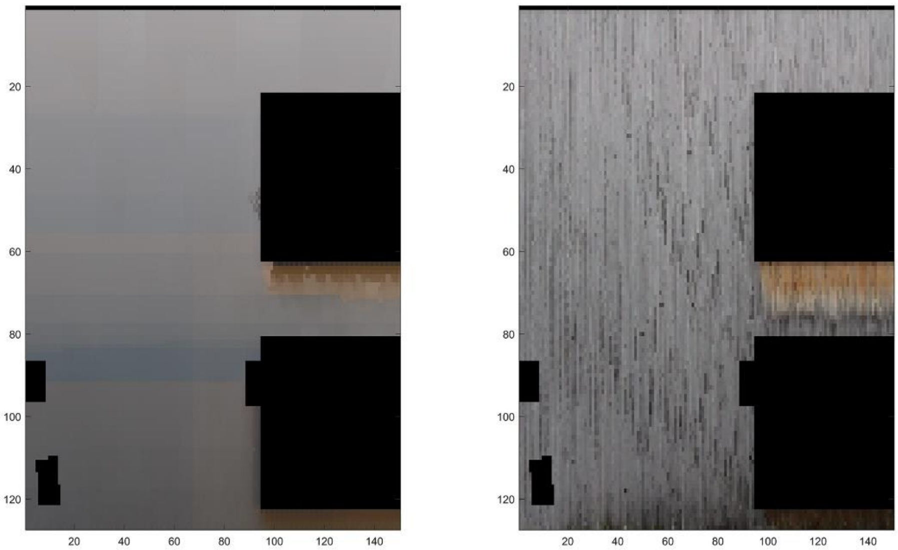


Figure 2. Photographic input to the colour model (right) and vizualisation of the simulated colour variation on the façade (left). The black rectangles correspond to white reference plates that were used to calibrate the RGB images.

References

Thiis, T., Burud, I., Kraniotis, D., Gobakken, LR. (2016) Application of simple surface climate models for modelling mould growth on wooden façades. I: Structures and Architecture Beyond their Limits. Taylor & Francis 2016

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

Performance of a noise barrier with different wood materials – results from a service trial after 20 years' exposure

Jöran Jermer[1], Stig Bardage[2], Pia Larsson Brelid[3]

[1] RISE, Box 5609, SE-114 86 Stockholm, Sweden, joran.jermer@sp.se

[2] RISE, Box 5609, SE-114 86 Stockholm, Sweden, joran.jermer@sp.se

[3] RISE, Gibraltargatan 35, SE-412 79 Gothenburg, Sweden, pia.larsson.brelid@sp.se

Keywords: noise barrier, service test, performance, preservative-treated wood, native wood

In connection with the construction of the Arlanda line, the railway connection between Arlanda airport and Stockholm city, an 11km long noise barrier made of untreated larch was built along parts of the track. This construction provided an opportunity to implement a full scale test study comparing different wood species and preservative treatments.

Thus, The Royal Institute of Technology (KTH) and SP Technical Research Institute of Sweden (now RISE) contacted the National Rail Administration in order to investigate the possibilities to install an extra number of sections made of preservative-treated wood and other untreated wood species. Following a positive response, nine test sections made of treated and untreated wood were installed in March1996. The overall aim of the study was to find the most appropriate wood material for a specific construction, in this case a noise barrier, with respect to durability and by extension to find the most ecological and economic wood material.

Each test section is approximately 4 meters long and 3.1 meters high. Water shedding features (wedge shaped strips) were incorporated to help keep moisture out of susceptible joints. The three bottom boards are partly in ground and called "waste boards".

Figure 1: Noise barrier shortly after installation in March 1996

The test barriers have been inspected a number of times since 1996. The most recent inspection was carried out in June 2016. All inspections have been carried out visually. At the base, soil was removed and the wood mechanically probed with a knife. For obvious reasons, only the back side (facing away from the railway tracks) could be inspected.

Table 1 Results after 8 and 20 years' exposure

Section	Treatment	Location	Condition 8 yrs	Condition 20 yrs
A	CCA Class AB	Above ground Below ground	Sound Slight decay	Sound Severe decay/Failure
B	Tanalith MCB (Cu, B tebuconazole)	Above Below	Sound Mod. decay	Spots only with slight decay Severe decay/Failure
C	Wolmanit CX-S (Cu, B, HDO)	Above Below	Sound Sound	Sound Slight/moderate decay
D	CCA Class AB	Above Below	Sound Slight decay	Sound Slight decay
E*	CCA Class A	Above Below	Sound Severe decay	Sound Failure
F	Scanimp KF (propiconazole)	Above Below	Sound Sound	Spots only with slight decay Severe decay
G**	Untreated pine	Above Below	Sound Sound	Spots only with slight decay Slight decay
H	Untreated spruce	Above Below	Sound Severe decay	Spots only with slight decay Failure
I	Untreated larch	Above Below	Sound Severe decay	Spots only with slight decay Failure
J	Royal treatment (Cu, BAC)	Above Below	Sound Slight decay	Spots only with slight decay Failure

* Waste board of untreated pine
** Waste board of CCA class A treated pine (Class A = for Use class 4; class AB = for Use class 3)

All sections (above ground) inspected were in good condition, also the sections of untreated wood for which evidence of decay was observed only in smaller spots, mostly in the triangular wedges.
Sections of preservative-treated wood had in general performed somewhat better, but two sections had minor spots of decay. None of the preservatives used for those sections are available on the market today. All untreated and treated sections, except for the CCA class A treated, had advanced decay in the boards in ground contact. Preservative-treated sections with decay consisted, as far as could be observed, of heartwood with insignificant penetration. Already after 8 years all untreated "waste boards" were severely decayed whereas most AB class treated boards showed slight to moderate decay, which is another evidence that class AB should not be used in ground if long service life is expected!

No other sections of the 11 km noise barrier have been inspected and nothing can therefore be concluded concerning the overall performance of the larch. Other exposure situations, e.g. where vegetation grows close to the barrier, means a higher risk and probability for decay compared to the exposure conditions for the test sections.

All sections were heavily subject to graffiti and it was not easy to evaluate any colour changes. However, the CCA-treated and Royal-treated sections seem to have kept their original colours best. The larch has become dark black and its colour is far from the pleasant original light reddish colour.

The trial shows that good design is crucial for the performance in above ground situations. With the present exposure situation, the untreated material and treated material has performed roughly equally well.

How do biotic and abiotic factors combine to affect the weathering of wood surfaces?

Julia Buchner[1], Mark Irle[1], Christophe Belloncle[1], Franck Michaud[1], Nicola Macchioni[2]

[1] Ecole Supérieure du Bois, LIMBHA, Rue Christian Pauc, 44306 Nantes, France
julia.buchner@ecoledubois.fr

mark.irle@ecoledubois.fr

christophe.belloncle@ecoledubois.fr

franck.michaud@ecoledubois.fr

[2] IVALSA, Via Madonna del Piano 10, 50019 Sesto Fiorentino, Italy macchioni@ivalsa.cnr.it

Keywords: abiotic factors, fungi, bacteria, artificial accelerated weathering, outdoor weathering

Using wood for exterior applications is currently rather fashionable in Europe, but, it is still used only in small quantities compared to e.g. concrete, steel and glass. Customers seek homogeneous, colourfast facades with low maintenance requirements. The visual appearance of a wooden facade changes over time through and, often, the discoloration is heterogeneous.

Extensive research on the decay of wood by fungi and bacteria in soil and water (durability classes 4 and 5) has already been carried out. Much less research has been conducted on wood in exterior use that is not in ground contact, i.e. durability class 3.2, which typifies the exposure conditions of facades.

The aim of this thesis is to identify any synergistic effects between biotic factors, such as bacteria, algae, moulds and fungi and abiotic factors, such as light, temperature and moisture on the weathering of wood surfaces in durability class 3.2. This approach will facilitate the design of stable wooden facades that require little maintenance over a long period of time.

Accelerated and outdoor weathering experiments will be carried out to see if and how environmental conditions and in particular, the presence of micro-organisms influence the weathering of wood.

One of the research objectives is to study the interactions between abiotic and biotic factors in a laboratory environment and therefore an artificial accelerated weathering experiment will be conducted. A study by Kataoke et al. (2007) shows that the depth of photodegradation is greater than indicated by other researchers such as Hon and Chang (1984) , because visible light was found to penetrate 540µm below the surface. Moreover the study shows that blue light can cause bleaching of the wood. Due to these findings and the fact that UV light is known to be an effective disinfectant, for this artificial accelerated weathering test the light source which is proposed to use by standards such as ASTM G0154 (ASTM-G0154-16:2007) and ISO 16474-1 (ISO 16474-1:2013) will be modified.

Another objective is to study the interactions between abiotic and biotic factors in natural conditions. The outdoor weathering experiment will be conducted in western France as well as in Italy. Meteorological data will be precisely recorded, consequently the degradation process of wood in two different regions can be compared to each other. This realistic experiment will allow researchers but also industry to understand the degradation process of the specific wood species.

Subsequently microbiological and molecular biology methods will be used to identify and quantify bacteria, moulds and fungi present in degraded wood facades in western France and Italy. A microcosm-scale experiment may reveal if certain bacteria have an influence on the growth rate of certain fungi and moulds or vice versa.

Douglas fir (*Pseudotsuga menziesii*) and oak (*Quercus robur*) will be examined due to the fact that these two species are commonly used for exterior applications in Europe. Moreover this choice allows the comparison between softwood and hardwood.

Several methods will be used to analyse the anatomical (SEM, light microscope), chemical (FTIR/ATR) as well as visual (colorimeter, roughness testing) changes in the degraded wood. The focus however is on the change in visual appearance of the weathered wood surface.

References

Hon, David N.-S.; Chang, Shang-Tzen (1984): Surface degradation of wood by ultraviolet light. In J. Polym. Sci. Polym. Chem. Ed. 22 (9), pp. 2227–2241. DOI: 10.1002/pol.1984.170220923.

Kataoka, Yutaka; Kiguchi, Makoto; Williams, R. Sam; Evans, Philip D. (2007): Violet light causes photodegradation of wood beyond the zone affected by ultraviolet radiation. In Holzforschung 61 (1). DOI: 10.1515/HF.2007.005.

ISO 16474-1, 2014: Paints and varnishes. Methods of exposure to laboratory light sources, International Organization for Standardization.

ASTM-G0154-16, 2016: Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials, ASTM International, West Conshohocken, PA, 2016.

Comparing hyperspectral imaging technology and visual assessment for mould growth on wooden surfaces

Ingunn Burud[1], Lone Ross Gobakken[2], Thomas Thiis[1], Andreas Flø[1]

[1] Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology, Campus Ås, PO Box 5003, 1432 Ås, Norway, ingunn.burud@nmbu.no

[2] Norwegian Institute of Bioeconomy Research, Pb 115, NO-1431 Ås, Norway

Keywords: mould growth, spectral imaging, wood substrates, visual assessment

Assessing mould growth coverage aesthetically implies that there is a need for quantification to allow objective numeric validation without considerable subjective evaluation. Visual assessment is the traditional and most common way to measure mould growth coverage on the surface of coated and uncoated wood in laboratory tests, field tests and in-situ on wooden building façades. Several standards used for this purpose describes a rating scale often from 0-3, 0-4 or 0-5 where 0 is no growth and 3, 4 or 5 are heavily infested or fully covered (EN927 2012, EN153 2011, EN15457 2014). The objectivity of using visual assessment is often questioned and there is an interest for finding additional or alternative methods for more objective assessment. Additionally, the rating scales in these standards are intended for testing coated materials or on surfaces where mould growth is an unwanted element. Therefore, these scales are often detailed in the start of the growth, so they capture well the onset of the growth, but lack the ability to assess the 'true' coverage regarding infestation and amount of discoloration. NIR hyperspectral imaging may give us a more complete picture of the fungal growth, both the quantity and the identity. With the long-term aim of understanding and determine prediction models for the mould growth exposed to different climates, we want to gather experience from using multisensory techniques, including RGB and hyperspectral imaging of fungal surface growth on a variety of wood substrates exposed in an outdoor environment. There is presently no method that determines the exact amount of mould growth on the samples. The results of this study are therefore comparisons of visual assessment and multi-sensory techniques with the aim of determining their different characteristics and what influences them.

Five different wood substrates (painted Spruce, non-treated Spruce, Pine, Aspen and acetylated Spruce) were exposed vertically facing north and south in Ås, Norway, in a specially designed test set-up (Fig. 1). The mould growth of the samples was evaluated by the means of visual assessment, RGB imaging and NIR (near infrared) hyperspectral imaging. The measurements were carried out at time intervals of two to three weeks, from August 2013 until January 2014, with the aim of determining mould growth curves on the different wood substrates.

A percentage of mould growth can be estimated from classification of NIR spectral images, such as shown for Aspen, on the North and the South side, displayed in Fig. 2. Moreover, the size of patches of mould can be determined. However, a certain percentage of mould growth may correspond to very different visual assessment values, since for example 50% mould growth coverage does not look the same when grouped in a few patches as when it is evenly distributed across the sample. In the present work, we will compare digital quantification of mould and visual assessment for all the five substrates. Advantages and inconveniences for the different techniques will be discussed in order to evaluate the best practice for various applications.

Figure 1: Experimental outdoor setup with five different wood substrates facing south, a white reference Spectralon and hyperspectral camera setup (left to right; coated spruce, spruce, pine, aspen, acetylated spruce).

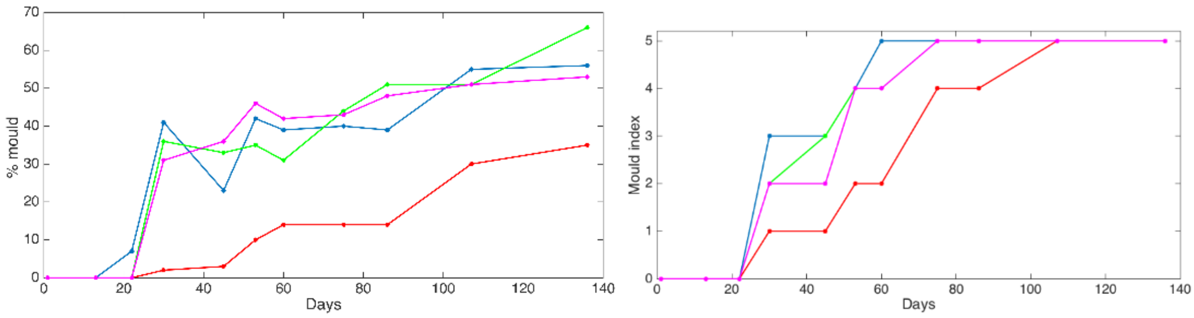


Figure 2: Growth curves for Aspen on North side from analysis of NIR hyperspectral images (left) visual assessment (right).

References

EN152 (2011) Test Methods for Wood Preservatives. Laboratory Method for Determining the Protective Effectiveness of a Prervative Treatment against Blue Stain in Service. European Committee for Standardization, Brussels.

EN927-3 (2012) Paint and varnishes. Coating materials and coating systems for exterior wood. Part 3: Natural wearhering test.

EN15457 (2014) Paints and varnishes - Laboratory method for testing the efficacy of film preservatives in a coating against fungi. European Committee for Standardization.

Acknowledgments:

This work has partly been funded by the Norwegian Research Council in the project "WOOD/BE/BETTER" code 225345.

Colour changes of wooden shingles treated with pine tar after weathering

Zuzana Vidholdová

[1] Technical University in Zvolen, T.G. Masaryka 24, Zvolen, SK 960 53, Slovakia,

zuzana.vidholdova@tuzvo.sk

Keywords: wooden shingles, pine tar, weathering

Wooden shingle is traditional and previously most widely used material in roofing construction in wooden rural and also in religious buildings in Slovakia. Surfaces of wooden shingles used in exterior are degraded by solar radiation as well as other environmental factor (Reinprecht 2016). Because ones are treated or finished using different types of chemicals with purpose of protection so that overall their service life extended.

The objective of this study was to evaluate discolouration of selected wooden shingles treated with pine tar as a result of weathering.

Table 1: Experiment set-up

Wooden shingles		Abbreviation	Treatment	Ageing Duration	Set Number
Larch	splitting	$LARCH_{Split}$	treated with Pine tar* untreated	1, 3, 6, 9	4
Spruce	splitting	$SPRUCE_{Split}$			
	cutting	$SPRUCE_{Cut}$			
Pine-thermally treated		$PINE_{Thermally\ treated}$			

*Chemical composition of pine tar was analyse in work Bubeníková – Vidholdová (2015)

Colours of surfaces of wooden shingles (table 1.) were analysed according to the CIE $L^*a^*b^*$ colour system using Colour Reader CR-10 (Konica Minolta, Japan). The colour coordinates L^* (darkness: white – black), a^* (red – green), and b^* (yellow – blue) of each sample were measured on its top surface in different exposure times. Measurements were performed for samples conditioned at a temperature of 20 $\pm$ 1 °C and a relative humidity of air 60 %. Values of L^*, a^* and b^* before and after test of natural ageing in exterior were used for calculation of the total colour change ΔE^* (figure 1) according to the equation: $\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$.

The greatest colour changes were found in pine tar finished wooden shingles at the beginning of weathering (after first month); this was mainly due to the chances in chemical composition of pine tar. On the other hand, with prolonged weathering colour the changes of untreated wooden shingle had continuous increase. Different wood species of used shingle before finishing had little or no effect on its colour stability during weathering.

Figure 1: Natural ageing of wooden shingles in the exterior exposure under a 45° slope orientated to the South at Technical University in Zvolen (from July to April)

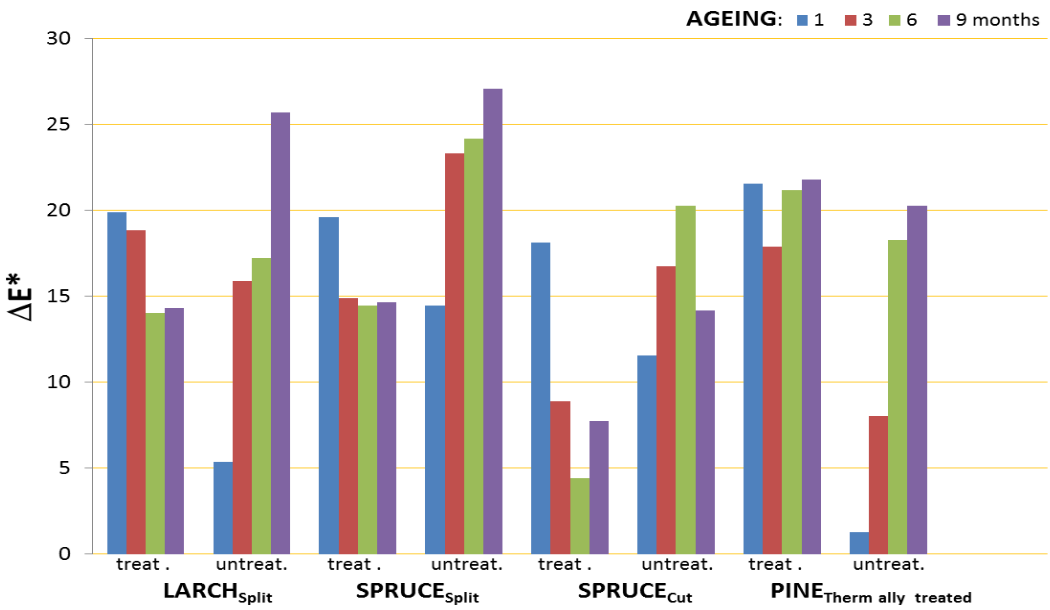


Figure 2: Total colour change ΔE^* during the weathering process

References

Bubeníková T., Vidholdová Z. 2015 Analyse of pine tar by GC-MS. In Selected processes at the wood processing : XI. international symposium, Hokovce 2015, Zvolen : Technical University in Zvolen, p. 99-103

Reinprecht L. 2016 Wood deterioration, protection and maintenance. John Wiley & Sons, Ltd, Chichester, UK, 357 p.

Acknowledgments:

This work was supported by Slovak Research and Development Agency - contract APVV-0200-12.

Surface characterisation of spruce to understand the effects of natural weathering.

Athanasios Dimitriou[1,2], Jakub Sandak[3], Anna Sandak[3]

[1] BioComposites Centre, Bangor University, Deiniol Road, Bangor, Gwynedd LL57 2UW, United Kingdom, bcs806@bangor.ac.uk

[2] Clifford Jones Timber, Brickfield Lane, Ruthin, Denbighshire LL15 2TN, United Kingdom, athdimitriou@hotmail.com

[3] Trees and Timber Institute/National Research Council (IVALSA/CNR), Via Biasi 75, 38010 San Michele all'Adige, Italy, sandak@ivalsa.cnr.it, anna.sandak@ivalsa.cnr.it,

Keywords: Wood weathering, surface characterisation, aesthetic performance, numerical modelling

Weathering is the process causing degradation of the biobased fibres by the weather conditions (e.g. solar radiation, temperature and moisture). The rate of weathering is affected by the wood species, specific climatic conditions and the pre-treatment of the material. Weathering affects the material through degradation of the surface. The breakage of the fibres leads to further penetration of the weather agents into the deeper layers, resulting to increase of the surface roughness, change of colour and glossiness. In consequence the aesthetic value of the material is reduced. The objective of this work, undertaken under a STSM within COST action FP1303, was to understand the weathering mechanism and kinetics that could lead to designing more effective preservation techniques. The other goal was to develop a prediction model of the aesthetic appearance that will be used for the estimation of the bio-materials' service life period, including maintenance/renovation planning.

Norway spruce samples, obtained from the same piece of wood to minimise variability, had been exposed to natural weathering at 18 sites across Europe for a weathering duration of 12 months (Round Robin test, of the COST Action FP1006 and FP1303). Every month one sample was collected and stored in a climatic chamber protected from light in order to avoid further degradation. Samples were characterized by means of several techniques in order to understand the different mechanisms which occur on wood surface during weathering. The following tests were performed:

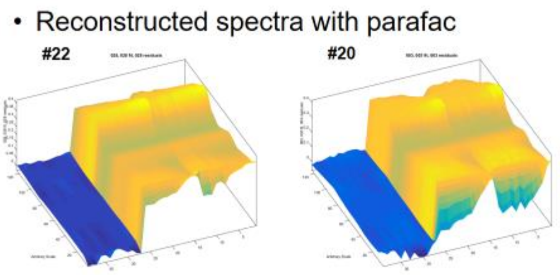
- Aesthetical changes
    - Colour
    - Imaging
    - Visual grading
    - Glossiness
- Chemical changes
    - FT-IR
    - FT-NIR
    - UV-VIS-NIR
    - Micro NIR
    - XRF

- Morphological changes
    - Laser displacement sensor
    - Laser line
    - Focus depth measurement

This study proved that the weathering effect is strongly influenced by the exposure location. The weathering kinetics showed similar trend in various magnitude among the different locations concerning the colour effect. The highest colour changes (ΔE) occurred in Turkey and the lowest in UK. It was also confirmed by the NIR spectra analysis that different chemical changes occur at the end of the weathering exposure because the spectral shape in both locations were different. This might be a result of diverse intensity of the degradation process, like hydrolysis and photo degradation, related to the specific weather conditions of the sample exposure.

Similar conclusions were drawn from the MicroNIR data analysis by means of PARAFAC method. Furthermore, it was possible to accurately model the NIR spectral changes along the exposure duration and location (Figure 1a). Additionally, visual grading showed that human perception of weathered wood is related to various factors like colour, glossiness and surface roughness. By means of Multiplicative Linear Regression (MLR) analysis (Figure 1b), it was possible to identify that the dominant factor that affects the human perception of wood degradation state is predominantly the colour. Roughness and glossiness of the surface were less important variables for degradation state evaluation. Therefore, MLR model might be used as support for prediction of the consumer aesthetic perspective and acceptance.

a)



b)

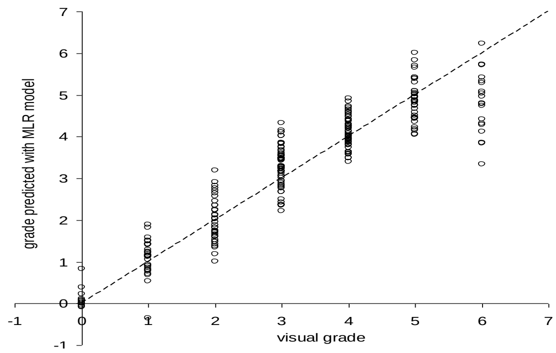


Figure 1: a) PARAFAC model of micro NIR results, b) MLR model of morphological characteristics and weather degradation visual grading

Acknowledgments: We would like to acknowledge COST FP1303 for funding this STSM and Trees and Timber Institute/National Research Council (CNR-IVALSA) for hosting Athanasios Dimitriou to undertake this research. Part of the research was performed during BIO4ever (RBSI14Y7Y4) project, funded within a call SIR (Scientific Independence of young Researchers) by MIUR. The Round Robin test was conducted with support of COST Action FP 1006 and FP1303.

COST FP 1303 Cooperative Performance Test – Results after two years' outdoor exposure

Boštjan Lesar[1*], Miha Humar[1], Christian Brischke[2], Linda Meyer-Veltrup[2], Dennis Jones[3], Nejc Thaler[1], Belloncle, C.[4], Abascal , J.M.[5], Alfredsen, G.[6], Brunnhuber, B.[7], Grodås, E.[6], Irle, M.[4], Kers, J.[8], Klamer, M.[9], Maider, A.B.[10], Mahnert, K.-C.[11], Melcher, E.[12], Palanti, S.[13], Pfabigan, N.[14], Suttie, E.[15], Touza, M.[16]

[1] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia, email: *bostjan.lesar@bf.uni-lj.si, miha.humar@bf.uni-lj.si, nejc.thaler@bf.uni-lj.si

[2] Leibniz University Hannover, Faculty of Architecture and Landscape Sciences, Hannover, Germany, email: brischke@ibw.uni-hannover.de, meyer@ibw.uni-hannover.de

[3] DJ Timber Consultancy Ltd, email: dr_dennisjones@hotmail.co.uk

[4-16] Address of authors, affiliation, and email address has first author

Keywords: wood, performance, English oak, Norway spruce, thermally modified wood, moisture content, degradation

This COST action started in October 2013 and an ambitious program was set up for four years. Among this a collaborative field test was planned. The idea of the cooperative performance test was to distribute a fairly simple test set up to as many places in Europe as possible in order to collect performance data reflecting the full range of climatic exposure conditions within the COST zone. Performance tables were exposed on 15th September 2014 at 27 different locations around Europe. A folding table with boards consisting of three different materials (i.e. Norway spruce, English oak and thermally modified spruce) was shipped as ready-to-use test object (Humar et al. 2014; Humar et al. 2015.). The boards were fixed half with stainless and half with galvanized screws. The evaluation data were prepared for the last two years. According to the schedule the following parameters were evaluated: fungal decay, discolouration, development of mould and other staining fungi, corrosion of fasteners, formation of cracks, moisture performance (only in tables version A; see Humar et al. 2014). Detailed guidelines for assessment were prepared together with Excel forms enabling easier comparison of the results.

At some locations, different versions of the tables were exposed. In this abstract the focus is on tables equipped with an electrical moisture data logger (Set version A) and without this electronical device (Set version B). After two years, we collected data from 15 locations in Europe. Colour changes were most prominent at all locations during first months of exposure. Samples became grey in the first year, afterwards colour changes were minor. After two years of exposure it was hard to find discoloration fungi on the upper side of the tables, because of greying of the samples. On bottom side discoloration was much smaller and stayed constant during exposure. After two years first decay and first fruit bodies were found on spruce samples exposed in Hamburg. At other locations and on other materials no decay was detected, yet.

The most challenging task during assessment was the evaluation of cracks. Cracks on samples are close related with moisture content / wetness of samples. The time since the last rain event, during which the specimen was allowed to dry was affecting the crack assessment. For the crack formations wood fibre orientation was also important. Exposed samples had different orientation of tree rings, and therefore rather big differences were found even between samples of the same material. On average, English oak specimens showed more and smaller cracks and Norway spruce and thermally modified spruce had longer cracks.

No corrosion was found on stainless steel screws after two years on all materials and locations. In contrast, galvanized screws corroded in English oak specimens and partly in thermally modified spruce specimens. On Norway spruce specimens, corrosion was found only on the bottom side of galvanized screws, which were fixed in copper based impregnated parts of the tables.

Figure 1: Fruit bodies of *Dacrymyces spp.* on Norway spruce specimens exposed in Hamburg (left) and corrosion of galvanized screws on English oak specimens exposed in Ljubljana (right) after two years of exposure.

References

HUMAR, Miha, BRISCHKE, Christian, LESAR, Boštjan, THALER, Nejc, et al. Introduction of the COST FP 1303 Cooperative performance test. V: Papers prepared for the 46th IRG Annual Meeting, Viña del Mar, Chile, 10th – 14th May 2015. IRG/WP 15-20567, 22pp.

HUMAR, Miha, BRISCHKE, Christian, MEYER, Linda, JONES, Dennis, THALER, Nejc, LESAR, Boštjan, ŽLAHTIČ, Mojca. COST FP 1303 Cooperative performance test - status update. V: KUTNAR, Andreja (ur.), et al. Performance and maintenance of bio-based building materials influencing the life cycle and LCA. Ljubljana: Biotechnical Faculty; [Koper]: University of Primorska, 2014, str. 45-47

Acknowledgments:

The authors acknowledge support of COST Action FP 1303, financial support from the Slovenian Research Agency within the framework of project L4-5517 and programme P4-0015 and infrastructure centre 0481-09 and support from Silvaprodukt d.o.o.. Special thanks are given to all of the participants.

Durability-based design of timber structures – Quantifying design, exposure, and resistance on the basis of dose-response relationships

Linda Meyer-Veltrup[1], Christian Brischke[2]

Leibniz University Hannover, Faculty of Architecture and Landscape Sciences, Institute of Vocational Sciences in the Building Trade, Herrenhäuser Straße 8,

D-30419 Hannover, Germany

[1]meyer@ibw.uni-hannover.de

[2]brischke@ibw.uni-hannover.de

Keywords: Decay, modelling, performance, service life prediction, timber structures

Service life of timber structures in outdoor conditions is predominantly affected by the climatic conditions in terms of moisture and temperature over time. On the one hand, the two parameters moisture content and temperature determine the exposure-induced dosage that can lead to fungal infestation and subsequent decay. On the other hand, the material resistance of wood stands in opposition to exposure and is itself affected by the inherent protective properties of wood and its ability to take up and release water in liquid or vaporous form. Other factors such as design details, in-use conditions, and maintenance are only indirectly affecting the service life of wooden structures and can be accounted for through the aforementioned parameters.

Current rethinking within European standardisation bodies leads to the development of performance related classification systems for timber products and requires delivery of respective performance data (Kutnik et al. 2014). The first attempts for comprehensive approaches to predict performance of wood products have been made in the frame of European research projects (e.g. WoodExter, WoodBuild, PerformWood).

A design principle inferred from a model approach to predict the field performance of wood based materials according to Brischke et al. (2014) and Isaksson et al. (2014) describes the climatic exposure on one hand and the resistance of the material on the other hand. Hereby acceptance for a chosen design is given if a load resulting from exposure conditions is less or at least equal to the material resistance (Fig. 1).

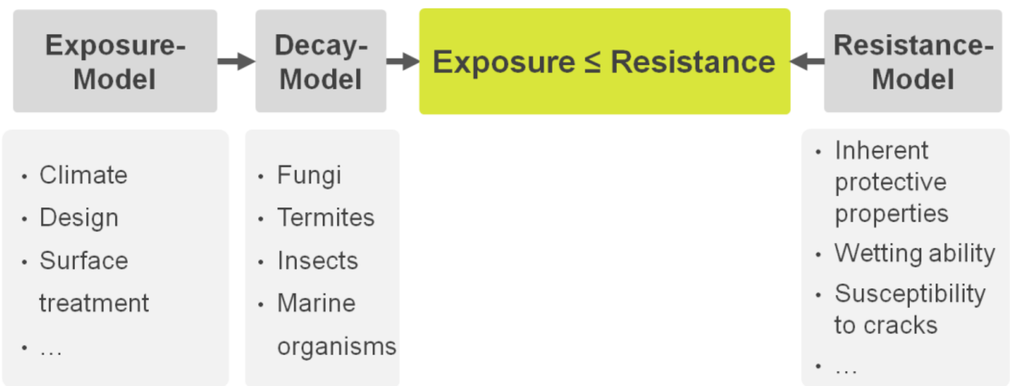


Figure 1: Design principle

Within the Swedish national research project 'WoodBuild' and within the European WoodWisdomNet project 'Durable Timber Bridges (DuraTB)' different exposure models (relationship between weather parameters and responding material climate) and decay models (relationship between material climate and responding decay) were developed. They have the potential to serve as instrument for design and service life prediction of timber structures. Several logistic decay models were applied and compared with respect to their feasibility to quantify direct and indirect decay influencing factors such as climate on macro, meso and micro level, topography, design details such as shelter through roof overhangs, end grain and side grain contact faces.

However, there is still a need for a methodology to implement the durability and moisture performance of wood in an engineering design method and performance classification system. Recently, a model approach based on the combined effect of wetting ability and durability has therefore been applied to long-term field test data to predict field performance of wood (Meyer-Veltrup et al. 2016). The concept does allow for quantifying the material resistance of untreated, modified and preservative treated wood using factors based on laboratory and field durability tests and short term tests for capillary water uptake, adsorption and desorption dynamics.

References

Brischke C., Meyer L., Hesse C., Van Acker J., De Windt I., Van den Bulcke J., Conti E., Humar M., Viitanen H., Kutnik M., Malassenet L. (2014) Moisture dynamics of wood and wood-based products – Results from an inter-laboratory test. The International Research Group on Wood Protection IRG/WP/14-20539

Isaksson T., Thelandersson S., Jermer J., Brischke C. (2014) Beständighet för utomhusträ ovan mark. Guide för utformning och materialval. Report TVBK-3066, Division of Structural Engineering, Lund University

Kutnik M., Suttie E., Brischke C. (2014) European standards on durability and performance of wood and wood-based products – Trends and challenges. Wood Material Science and Engineering 9, 122-133

Meyer-Veltrup L., Brischke C., Alfredsen G., Humar M., Flæte P.-O., Isaksson T., Larsson Brelid P., Jermer J. (2016) The combined effect of wetting ability and durability on field performance – verification of a new prediction approach. Wood Science and Technology. Submitted for publication

Seventh-year durability analysis of post-treated wood-based composites

Cihat Tascioglu[1], Tsuyoshi Yoshimura[2]

[1] Department of Forest Products Engineering, Faculty of Forestry, Duzce University, Duzce, Turkey, 81620, cihattascioglu@duzce.edu.tr

[2] RISH, Kyoto University, Gokasho, Uji, Kyoto, Japan, 611-0011

Keywords: wood-based composites, wood-plastic composites, field test, post-treatment

The production of wood-based composites (WBCs) has increased considerably over the past few decades and they have been utilized under conditions conducive to biological attacks. Unfortunately, these composites are prone to decay fungi and termite attacks if utilized without preservative treatments. There are two major procedures to protect WBCs and WPCs. The post-manufacturing treatment is applied after the production of such composites and does not require any modification in composite manufacturing lines while some side effects on mechanical properties are reported. In-line treatments, incorporating biocides during the manufacturing process, might require some modifications on the manufacturing process but provides full protection throughout the board thickness.

Alkaline copper quat (ACQ) and copper azole (CA) which have been accepted worldwide as alternatives to chromated copper arsenate (CCA), were evaluated as wood preservatives for post-manufacturing treatment of WBC in the present research.

Specimens were prepared from five commercially available structural-use wood-based composites: softwood plywood (SWP), hardwood plywood (HWP), medium density fiberboard (MDF) produced from hardwood fibers, aspen oriented strand board (OSB) and particleboard (PB) made of both hardwood and softwood particles. The specimen sizes were 100 mm x 100 x thickness for field tests. ACQ and CA were tested for their effectiveness at three retentions, respectively K1, K2 and K3 classes as designated by JAS.

Untreated and treated wood based composite specimens were tested for their changes in mechanical properties due to preservative treatments by the JIS three-point bending method. A previously developed system to simulate performance of sill plates (dodai) in traditional Japanese homes was used in the field tests.

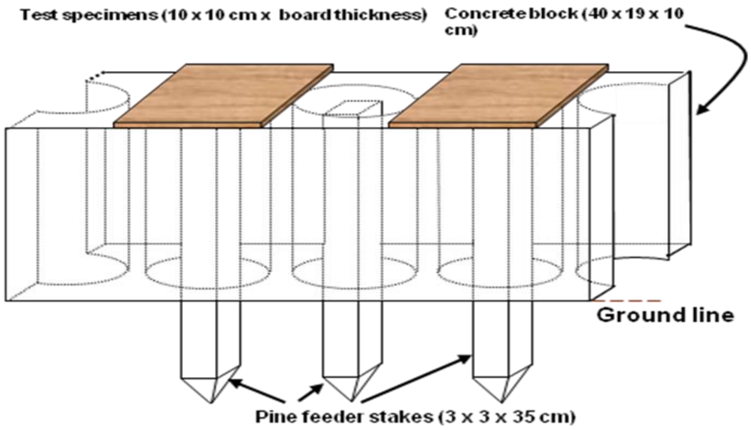


Fig. 1. Installation details of specimens and feeder stakes in the Living Sphere Simulation Field (LSF) of RISH, Kagoshima, Japan.

The findings indicate that wood-based composites tested are not durable enough, even in protected above ground conditions, if they are used without protective treatment, with the exception of MDF. MDF displayed high natural durability and might be used under less hazardous conditions based on 7-year exposure data. Post treatment with ACQ and CA at the retention levels tested significantly enhanced termite resistance of SWP, HWP, OSB and PB but failed full protection at the end of 84 months' period.

References

Gardner, D. J., Tascioglu, C. and Walinder, M E B. 2003. Wood composite production [In]: Wood deterioration and preservatives: Advances in our changing world (Ed. by Goodell, B. Nicholas, D. D. and Schultz). Am. Chem. Soc., Washington, D. C., 399-419

Grace, J. K., Oshiro R. J., Byrne, T., Morris, P. I., Tsunoda, K. 2000. Termite resistance of borate-treated lumber in a three-year above ground field test in Hawaii. The Int. Res. Group on Wood Protection Doc. No. IRG/WP 00-30236, Stockholm, Sweden

Kartal, S.N. and Green F III. 2003. Decay and termite resistance of medium density fiberboard (MDF) made from different wood species. International Biodeterioration and Biodegradation. 51(1):29-35

Development of an algorithm for computation of the weather dose used for natural weathering models

Jakub Sandak[1], Anna Sandak[1], Ingunn Burud[2], Thomas Thiis[2], Dimitrios Kraniotis[3], Athanasios Dimitriou [4]

[1] Trees and Timber Institute/National Research Council (IVALSA/CNR), Via Biasi 75, 38010 San Michele all'Adige, Italy, sandak@ivalsa.cnr.it, anna.sandak@ivalsa.cnr.it,

[2] Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology, Campus Ås, Universitetstunet 3, P.O. box: 5003, 1432 Ås, Akershus, Norway, ingunn.burud@nmbu.no, thomas.thiis@nmbu.no

[3] Oslo and Akershus University College of Applied Sciences, P.O. box: St. Olavs plass 4, 0130 Oslo, Norway, dimitrios.kraniotis@hioa.no

[4] BioComposites Centre, Bangor University, Deiniol Road, Bangor, Gwynedd LL57 2UW, United Kingdom, athdimitriou@hotmail.com

Keywords: wood weathering, numerical modelling, aesthetical performance

The research presented is a result of STSM performed within COST action FP1303. The goal was to develop a novel numerical model for computation of the weather dose (*D*), defined as an amount of energy provided to the system and affected the changes of material due to weathering, on the base of meteorological data and other geo databases. It could be considered as an alternative approach for assessing incursion of the environment, including longitude, latitude, solar radiation, rain and air humidity. The model provides a single (or multiple) indicator precisely quantifying the weather dose to be later used for determination/modeling of the aesthetical changes of biomaterials exposed to natural weathering as well as for technical characteristics influencing service life performance. The challenge is to apply the appropriate numerical procedures and algorithms to the available data, but most of all to define an original approach for the weather dose determination.

A preliminary numerical model to be used for explaining weathering process of biomaterial (wood) was developed with a set of samples exposed in Ås (Norway). This test was conducted in parallel to the COST Actions FP1006 and FP1303 Round Robin test program, with higher frequency of sample collection. The test was conducted on the private building located in an open field, therefore allowing direct access of the sun radiation during the whole test. Five cycles of sample exposure were performed, each of 21 days duration. All samples within single cycle were exposed together, but the collection moment (and resulting exposure duration) was different for each sample. The collection frequency was 1 sample/set/day. Five consecutive cycles were conducted in total assuring the time shift of one week. The samples were stored after collection in a dark climatic chamber in order to avoid any further weathering. All the samples were carefully characterized after the experimental campaign including:

- NIR hyperspectral imaging
- TGA
- CIE Lab
- FT-NIR
- X-ray attenuation mapping

The detailed weather data were acquired from the local weather station located closely to the exposure site. The weather dose (*D*), was calculated directly on the base of CIE L, CIE a, CIE b and CIE dE (as linear interpolation of the tabular values obtained with the fitting function). Alternatively, *D* can be calculated by means of the weather index obtained with chemometric modelling methods, such as PLS.

The main goal of the developed software (Fig. 1) is to visualize the whole collection of the available results corresponding to each sample form the RR test, including:

- appearance of the weathered sample
- measured CIE LAB colour coordinates
- modelled CIE LAB colour coordinates
- RGB colour coordinates and distribution on the image (histogram)
- weather data: (surface temperature, relative humidity, direct solar radiation, cumulative hours of relative humidity >80% and cumulative solar radiation during the period of the sample exposure).

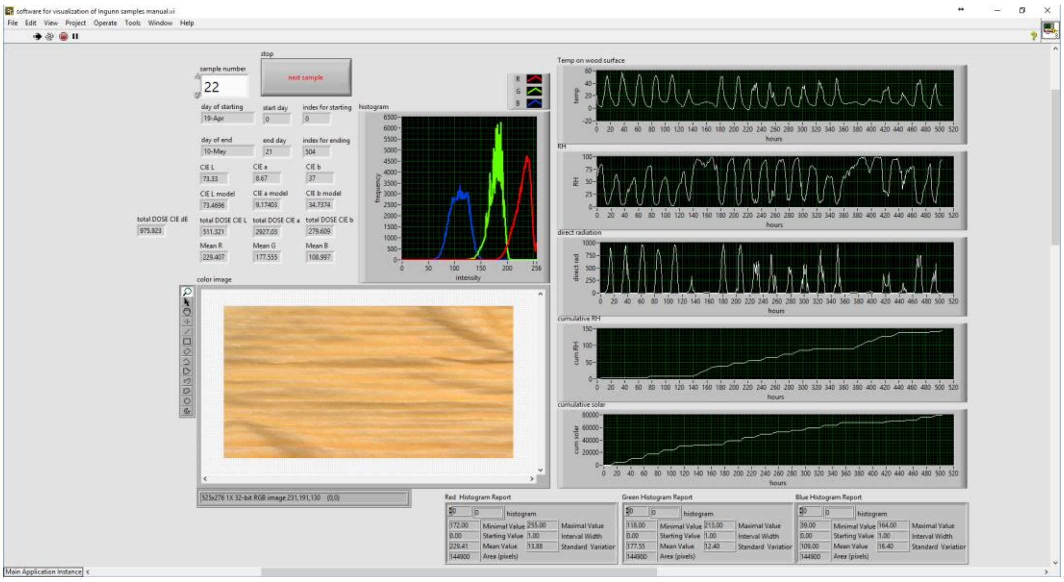


Figure 1. The user interface of the software usable for analysis of the weathered wood samples

The software is recently updated to accommodate weathering data from other locations and visualization of the additional characteristics available for other samples

Acknowledgments:

Presented work was conducted during BIO4ever (RBSI14Y7Y4) project funded within a call SIR (Scientific Independence of young Researchers) by MIUR. The support of COST FP1303 for funding Short Term Scientific Missions of Thanasis Dimitriou and Jakub Sandak is greatly acknowledged.

Fungal susceptibility testing of bio-based building materials: using image analysis as an assessment tool

Liselotte De Ligne[1,2], Guillermo Vidal-Diez de Ulzurrun[1,2], Jan Van den Bulcke[1], Jan M. Baetens[2], Bernard De Baets[2], Joris Van Acker[1]

[1] Coupure Links 653, 9000 Gent, Belgium, Ghent University, Department of Forest and Water Management, Laboratory of Wood Technology, liselotte.deligne@ugent.be

[2] Coupure Links 653, 9000 Gent, Belgium, Ghent University, Department of Mathematical Modelling, Statistics and Bio-informatics, Research Unit KERMIT

Keywords: bio-imaging, fungal susceptibility, bio-based materials

When an organic material is exposed to favourable moisture and temperature conditions as well as to degrading organisms, its functional and aesthetic service life can decrease. Fungi can cause structural damage and lead to degradation of bio-based materials (Bertron 2014, Dedesko & Siegel 2015). It is, for example, well known that most wood products used in outdoor environments must be protected against deterioration by decay fungi, such as white and brown rot fungi (Goodell et al. 2003).

Vidal-Diez de Ulzurrun and co-authors (2015) developed an automated method capable of assessing fungal growth through time and space. The experimental set-up (Fig. 1) allows for a functional description of fungal growth dynamics and a quantitative mutual comparison of different growth behaviours. Through a combination of image analysis and graph theory (Fig. 2), several fungal growth features (area and total length of the mycelium, number of tips, growth angle, etc.) can be extracted from images of growing fungi (Vidal-Diez de Ulzurrun *et al*. 2015).

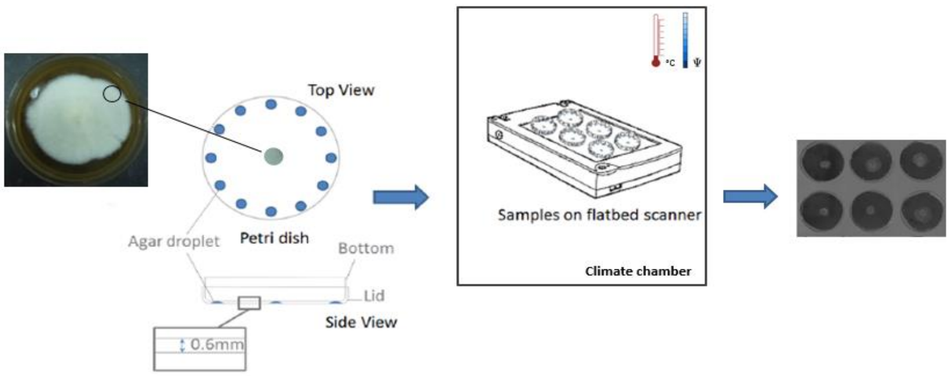


Fig. 1 Scheme of the experimental set-up.

The method has successfully been applied to the analysis of fungal growth for several fungal species (*Coniophora puteana, Rhizoctonia solani*, etc.), varying environmental conditions and varying concentrations of one particular growth medium, being malt agar (Vidal-Diez de Ulzurrun 2016). As this approach allows to quantify fungal growth of an entire mycelium in an automated way, we would like to examine its potential as a tool for fungal susceptibility testing of bio-based materials.

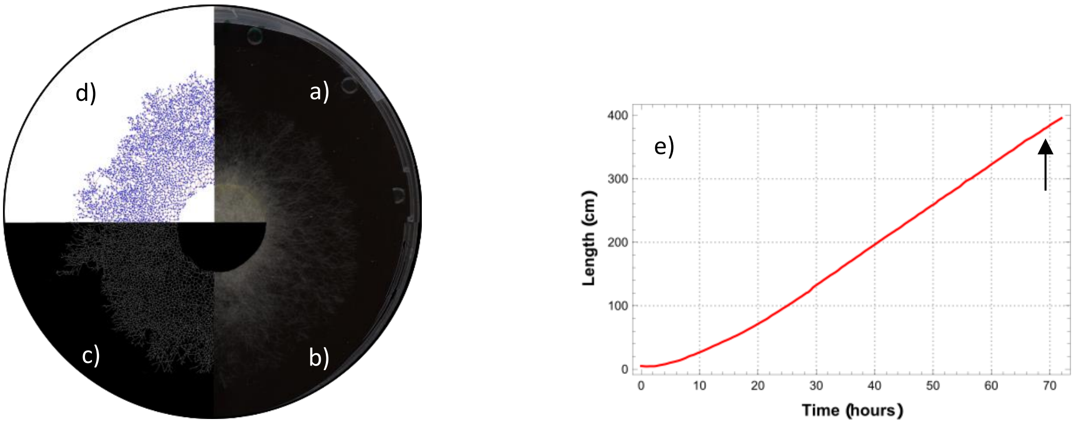


Fig. 2. Summary of the complete process of fungal growth feature extraction from an image of *Coniophora puteana* growing in vitro at 75% RH and 20°C after 70 hours. a) Initial image; b) Preprocessed image; c) Binary ridge map; d) Mathematical graph; e) Fungal feature 'total length of the mycelium' as a function of time, the arrow indicates the area of the mycelium at the moment the picture on the left was taken.

For this purpose, the spatial structure of the bio-based material will have to be largely removed, as the growing height in the experimental set-up is restricted to 0.6 mm (Fig. 1). This restriction of the fungal growth to two dimensions is necessary because overlapping hyphae would otherwise not be identifiable. Removing the structure could for example be done by taking a micro section of a bio-based material or by milling and creating a paste out of it. This approach is interesting, as the effect of only the chemical components of a material on fungal susceptibility can be examined when the spatial structure is eliminated.

References

Bertron, A., 2014. Understanding interactions between cementitious materials and microorganisms: a key to sustainable and safe concrete structures in various contexts. Materials and Structures 47, 1787–1806.

Dedesko, S., Siegel, J.A., 2015. Moisture parameters and fungal communities associated with gypsum drywall in buildings. Microbiome 3 (71).

Goodell, B., Nicholas, D.D., Schultz, T.P., 2003. Wood deterioration and preservation: Advances in our changing world. Oxford University Press, Oxford, United Kingdom.

Vidal-Diez de Ulzurrun, G., Baetens, J. M., Van den Bulcke, J., Lopez-Molina, C., De Windt, I., De Baets, B., 2015. Automated image-based analysis of spatiotemporal fungal dynamics. Fungal Genetics and Biology 84 (2), 12–25.

Vidal-Diez de Ulzurrun, G., 2016. Fungal growth modelling and assessment: Towards a lattice-free three-dimensional fungal growth model, PhD Thesis, Ghent University, Ghent, Belgium.

Acknowledgments

FWO. Research Foundation Flanders (Fonds Wetenschappelijk Onderzoek – Vlaanderen).

Sorption hysteresis of selected structural wood – based composites

Aneta Gumowska[1], Grzegorz Kowaluk[2]

[1] Warsaw University of Life Sciences, Faculty of Wood Technology, Nowoursynowska Str. 159, 02-787 Warsaw, Poland, aneta5g@wp.pl

[2] Warsaw University of Life Sciences, Faculty of Wood Technology, Nowoursynowska Str. 159, 02-787 Warsaw, Poland, grzegorz_kowaluk@sggw.pl

Keywords: hysteresis, sorption, equilibrium moisture content, thickness change, hygroscopic

Thermal insulation wood-based composites used in construction should have high insulation properties, which are influenced by i.a. density (Sekino 2016) and temperature (Troppova et al. 2015) and are significantly dependent on moisture content because with increasing moisture content thermal conductivity raises. This explains the importance of the initial moisture content of wood-based boards and climate parameters under which they were stored before their intended use. Despite storage at the same air temperature and moisture, the equilibrium moisture content of boards does not achieve the same level, which impacts on the insulation properties. The relevant standards specify only conditioning the samples under controlled climate conditions immediately before testing, but do not include parameters of the samples before such conditioning. The aim of this research was to investigate the influence of pre-conditioning parameters on the equilibrium moisture content of selected wood–based composites for structural purposes.

The investigated materials in this work were thermal insulation wood–based composites and construction and building boards (MDP, MFP, particleboard). During research the sorption properties were characterized to measure moisture equilibrium and determine the relative (respect to initial thickness) change in thickness. All the tested wood – based composites were divided into two categories:

1) prior to testing dried at 105°C to constant weight (0% moisture content);
2) humidified in air with a relative humidity about 100% and at 23°C to constant weight.

Then all the samples were conditioned under the same air conditions (20°C and relative humidity in the range of 30 – 35%). The weight and thickness of the samples were measured after 409, 936 and 984 hours of conditioning. The moisture content was conducted by oven dry method, on 5 samples from each board type.

The results show that the preliminary preparation of the tested samples (dried or humidified) has a significant influence on their equilibrium moisture content. The selected results of the equilibrium moisture content measurement for the particleboard are displayed on figure 1 and for the insulation mat on figure 2. Samples humidified / dried and then conditioned under the same conditions finally do not reach the same equilibrium moisture (moisture content hysteresis). Among all the tested boards, the highest hysteresis value, 3.2%, was for the insulating mat and the lowest, 1.6% for particleboard. Such high difference of equilibrium moisture content of wood fibrous insulation panel can significantly influence the insulation properties during use as well as when testing the thermal conductivity characteristics.

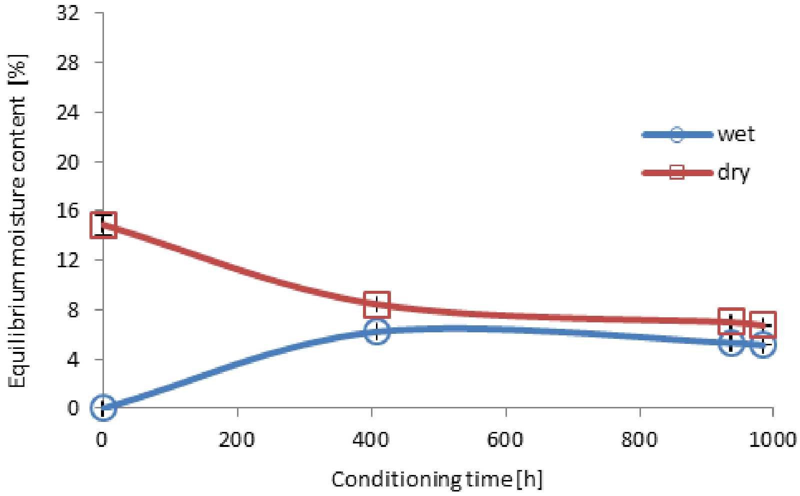


Figure 1: The equilibrium moisture content for the single layer particleboard

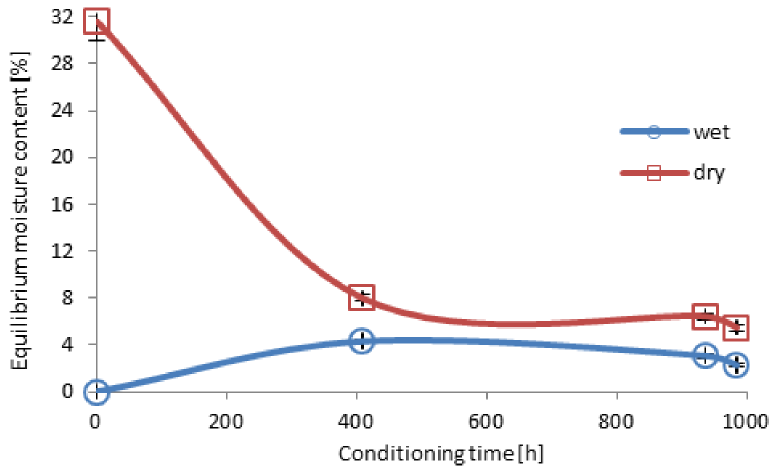


Figure 2: The equilibrium moisture content for the insulating mat

References

Sekino N. (2016): Density dependence in the thermal conductivity of cellulose fiber mats and wood shavings mats: investigation of the apparent thermal conductivity of coarse pores. J Wood Sci 62: 20–26. DOI 10.1007/s10086-015-1523-6

Troppová E., Švehlík M., Tippner J., Wimmer R. (2015): Influence of temperature and moisture content on the thermal conductivity of wood-based fibreboards. Materials and Structures 48:4077–4083. DOI 10.1617/s11527-014-0467-4

Some aesthetic decorative features of varnished surfaces

Emilia-Adela Salca,[1] Tomasz Krystofiak,[2] Barbara Lis[3]

[1] Faculty of Wood Engineering, Transilvania University of Brasov, Universitatii 1, 500068, Brasov, Romania, email: emilia.salca@unitbv.ro

[2] Faculty of Wood Technology, Poznan University of Life Sciences, Wojska Polskiego 28, 60-637, Poznan, Poland, email: tomkrys@up.poznan.pl

[3] Faculty of Wood Technology, Poznan University of Life Sciences, Wojska Polskiego 28, 60-637, Poznan, Poland,email: blis@up.poznan.pl

Keywords: adherence**,** black alder, chemo-resistance, dry heat test, gloss

The present study focuses on some decorative features of coated surfaces of black alder wood (*Alnus glutinosa* Gaertn. *L.*) as a function of two eco-varnish types. Adhesion strength, surface glossiness and the effects of dry heat test and chemo-resistance were evaluated.

Planed specimens made of black alder wood were subjected to parallel sanding with two grit sizes, 100 and 150, respectively. Two eco-varnish products, such as 100% UV and water-borne, were applied by spraying in two layers under laboratory conditions. A light sanding with 220 grit size sandpaper was applied prior to the second varnish layer. The curing process was separately performed by using a UV unit for the samples coated with 100% UV product and the samples coated with the water-borne varnish were cured under laboratory conditions.

The adhesion strength and the surface glossiness were measured with the help of the PosiTest-AT type adhesion tester and the PICO GLOSS 503 gloss meter, respectively. The resistance to dry heat was carried out to evaluate the effect produced by the contact of the coated surface with a hot object heated at the temperature of 70°C. The chemical resistance of the coated surfaces was determined by using four types of liquids, namely paraffin, water, alcohol and coffee.

The samples coated with the water-borne product presented higher adherence values (1,39 MPa) when compared to those specimens varnished with the UV product (1,13 MPa). But the samples varnished with the UV product exhibited better glossiness at 60° geometry.

The results after the dry heat test showed that the high temperature applied on the surface influenced the surface glossiness (Fig. 1).

Alcohol was noticed to be the strongest agent, it produced the surface deterioration very fast, while coffee, paraffin and water did not produce much changes.

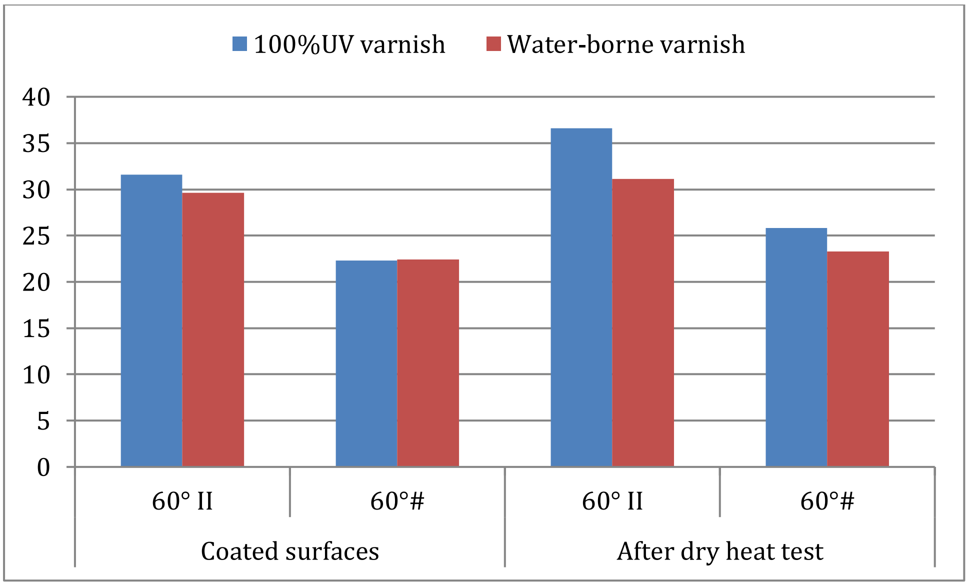


Figure 1: Variation of gloss as a function of varnish type and resistance to dry heat

References

Cakicier N., Korkut S., Sevim Korkut, D. 2011. Varnish layer hardness, scratch resistance, and glossiness of various wood species as affected by heat treatment. BioResources 6, 2: 1648-1658

Nejad M., Shafaghi R., Ali H., Cooper, P. 2013. Coating perfomance on oil-heat treated wood for flooring. BioResources 8, 2: 1881-1892

Acknowledgments:

The authors acknowledge the support received from Transilvania University of Brasov in Romania, the Division of Gluing and Finishing of Wood from the Faculty of Wood Technology in Poznan, and Remmers Company in Poland to perform this study.

Artificial weathering effects on glue bond, varnish stability and surface appearance in thermally modified larch

Raisa Teciu[1], Morwenna Spear[1]

[1] The BioComposites Centre, Bangor University, Deiniol Road, Bangor, LL57 2UW, U.K. m.j.spear@bangor.ac.uk

Keywords: bioinspired design, cell wall, turgor pressure, architecture, built walls

Thermal modification is an established form of wood modification, leading to enhanced dimensional stability. It may be used to add value to readily available timbers, not only due to greater suitability for joinery products resulting from reduced moisture movement but also aesthetic benefits. Thermal modification alters the colour, working properties, lustre and finish; it is also reported to assist in rapid transformation of the timber to a weathered silver-grey when used in building exterior cladding. This study was prompted by an interest in observing weathering effects under replicable conditions to compare thermally modified timbers.

A QUV artificial weathering test based on EN 927-6 was conducted using twelve weeks of a combined UV rainfall simulation (6 days), with a one day exposure to humidity. This places significant strain on any paint films or glue joints, providing a challenging test method, enabling comparison of film performance and bonding. Samples were designed to minimise and to maximise the variety of strain at the glue-line by deliberately favouring matching (e.g. radial to radial) or poor (e.g. tangential to radial) combinations of growth ring alignment. In addition, combinations of mild and moderate thermal modification were placed in adjacent glue-lines. Samples were removed, measured and observed at each one week cycle. A polyurethane adhesive was used for all samples, and bonding remained good through the 12-week period. The performance of a high gloss varnish was also monitored.

Updating the Reliability of cracked timber structures by using experimental results and numerical fracture model

T-B Tran[1], E. Bastidas-Arteaga[1], Y. Aoues[2], R. Moutou Pitti[3], S.E Hamdi[3], C.F. Pambou Nziengui[3], E. Fournely[3]

[1] University of Nantes, Nantes, France thanh-binh.tran@etu.univ-nantes.fr, emilio.bastidas@univ-nantes.fr

[2] Normandie Univ, INSA Rouen Normandie, France younes.aoues@insa-rouen.fr

[3] Université Clermont Auvergne, Clermont-Ferrand, France Rostand.MOUTOU_PITTI@univ-bpclermont.fr

Keywords: Reliability, timber, cracks, Bayesian network, Cast3m, climate variations

Introduction

In timber structure, cracking initiation is frequently recognized as a main cause leading to structural failure (Riahi et al 2016). Especially, mechanical behaviours of timber are affected by environmental conditions: moisture, temperature, etc. These hydrothermal conditions could produce a higher risk of crack growth in timber structures (Dubois et al 2009). The fracture studies in timber structure therefore should take into accounts these conditions. In numerical modelling, the crack initiation and crack propagation are studied in terms of computing energy release rates (Moutou Pitti et al 2010). A limit state representing the collapse event of timber structures could be defined from the energy rate. However, in real practice it is difficult to obtain these parameters.

This study aims to propose a methodology for assessing and updating the reliability of timber structures with cracks from experimental data and by coupling probabilistic approach and numerical fracture models. The proposed approach is based on updating of prior information by newly obtained measurements which is conducted by a Bayesian approach. The principle is to use coupled mechanical-probabilistic approach to generate a database for constructing a Bayesian Network (BN) representing for structural performance. An experiment on a beam Douglas wood exposed to external environment was developed to obtain real data about the variation of temperature and deflections of the beam. These data are introduced into BN for updating structural reliability. The results showed that this methodology is useful for reliability assessment of structures from experimental data.

Results

In the mechanical stage, a Finite Element Method (FEM) model on Cast3m is constructed for modeling a timber beam with cracking subjected to TVHM. In this model, the invariant integral A (including a temperature variation) are generalized to crack propagation in orthotropic media by using the MMCG (Mixed Mode Crack Growth) specimen which ensures the stability of the propagation path during the process in mode I, mode II or mixed mode. In the probabilistic stage, a number of simulations are performed and in each simulation, a vector of random variables representing for a set of input parameters is generated for processing the FEM model. The output from each FEM processing is the displacement and the energy release of the beam. The input and the output data from the numerical model are used to construct the Bayesian Network (BN). Structural reliability assessment is updated by introducing measurement data into BN as evidences. Real data from experiments (temperatures and deflections) (Figure 1a) are introduced into BN as evidences for updating the probability of failure. Results from BN updating presented in Figure 1b reveals that the increasing in temperature and deflection will increase significantly the failure risk of the timber structures subjected to crack.

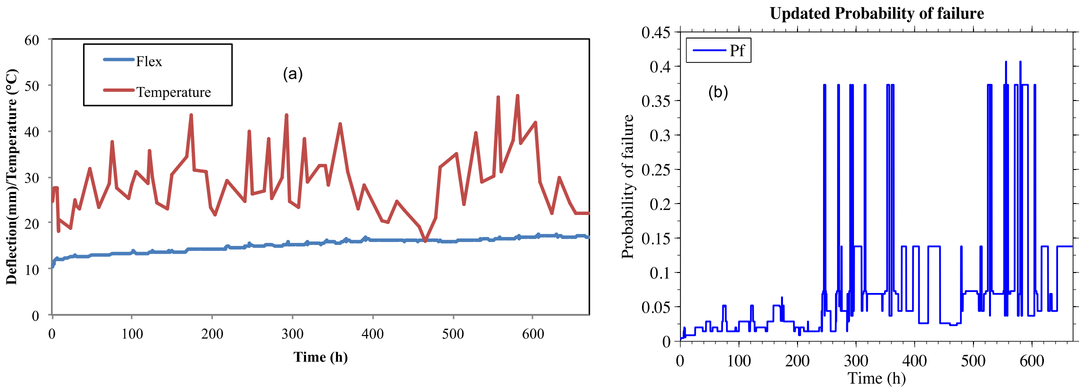


Figure 1. (a) The measurements of temperature and deflection; (b) The updated probability of failure.

Conclusions

In timber structures subjected to cracking, the variations of temperature and deflections have important influences on its serviceability and safety. This research proposed a coupled mechanical-probabilistic approach with Bayesian Network (BN) to facilitate the representation of the structural performances. The obtained results showed that this approach is useful for assessing and updating the reliability of timber structure from experimental data.

References

F. Dubois, R. Moutou Pitti and J. Husson. Thermodynamic approach about fracture modeling under mechano-sorptive loading. in SEM Annual Conference, 2009, no. 1.

H. Riahi, R. Moutou Pitti, F. Dubois and A. Chateauneuf. Mixed-mode fracture analysis combining mechanical, thermal and hydrological effects in an isotropic and orthotropic material by means of invariant integrals, Theor. Appl. Fract. Mech., 2016;85:424-434.

R. Moutou Pitti, F. Dubois and C. Petit. Generalization of T and A integrals to time-dependent materials: analytical formulations, Int. J. Fract., pp. 2010; 161:187–198.

Acknowledgments

The authors would like to acknowledge the financial support of project CLIMBOIS ANR-13-JS09-0003-01 as well as the labelling of the ViaMéca French cluster.

Research on modified floorboard of higher hardness

Izabela Burawska[1], Piotr Boruszewski[1]

[1] Faculty of Wood Technology SGGW, Nowoursynowska 166, 02-776 Warsaw, Poland

Keywords: densification, hot rolling, surface modification, mechanical parameters

The aim of research was to determine the physico-mechanical properties of densified floorboards. The floor elements (70x490x11mm) consisting of 3.8 mm thick wear layer were subjected to hot rolling densification. During modification, temperature of hot rolls and a rolling pressure were a variable factor, influencing a thickness of surface deformation.

To evaluate the influence of densification parameters on physico-mechanical properties, 5 groups of samples were tested:

- 0 - control sample, not densified,
- 1/100 – samples densified by 1mm using hot rolls with temperature of 100°C,
- 2/100 – samples densified by 2mm using hot rolls with temperature of 100°C,
- 4/100 - samples densified by 4mm using hot rolls with temperature of 100°C,
- 2/200 - samples densified by 2mm using hot rolls with temperature of 200°C.

Within the framework of studies, the density distribution in floorboards were determined (fig. 1), which allowed to define the thickness of upper layer of modified surface, as well as its adjustment along the element. An increase in density was observed in case of samples with modified surface.

Additionally, the hardness of the modified surface was determined on the basis of EN-1534 standard. According with the recommendations of the standard, a steel ball was pressed into the surface with force value of 1kN by 25 seconds. After that, a diameter of the interference was measured using a microscope, combined with a digital camera and a software NIS-Elements D2.30. The test results for the different variants of materials are shown in fig. 2. It was observed that modification of the surface layer of the floorboard increases surface hardness, however the impact of wood anatomy and anisotropy of the surface layer is noticeable.

The next stage of the study included surface wettability and surface free energy determination. Then scratch and abrasion resistance was determined for each of group of samples. It was found that an increase in the temperature of surface modification increase its fragility, which negatively affects the resistance to scratches and abrasion.

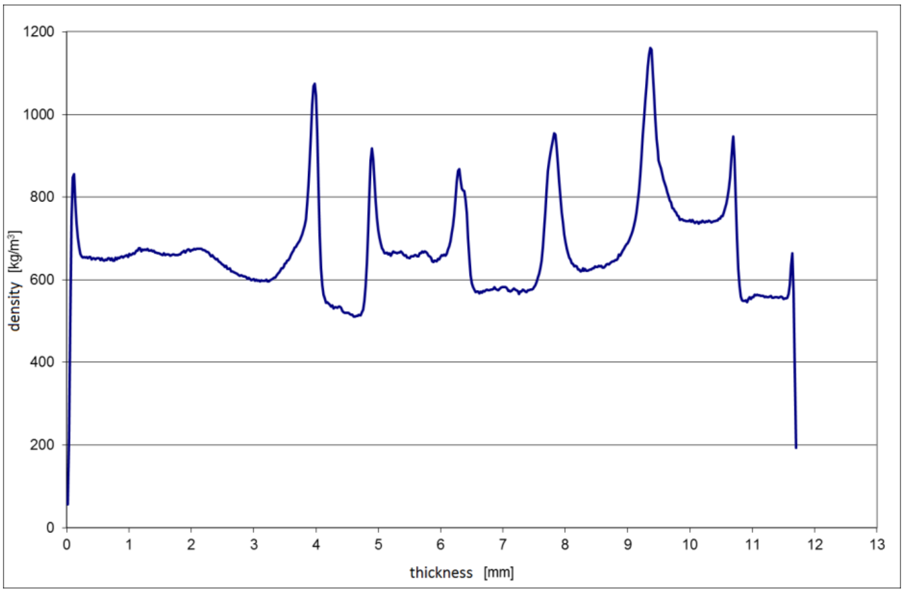


Fig. 1. Density distribution in floorboard of 1/100 group

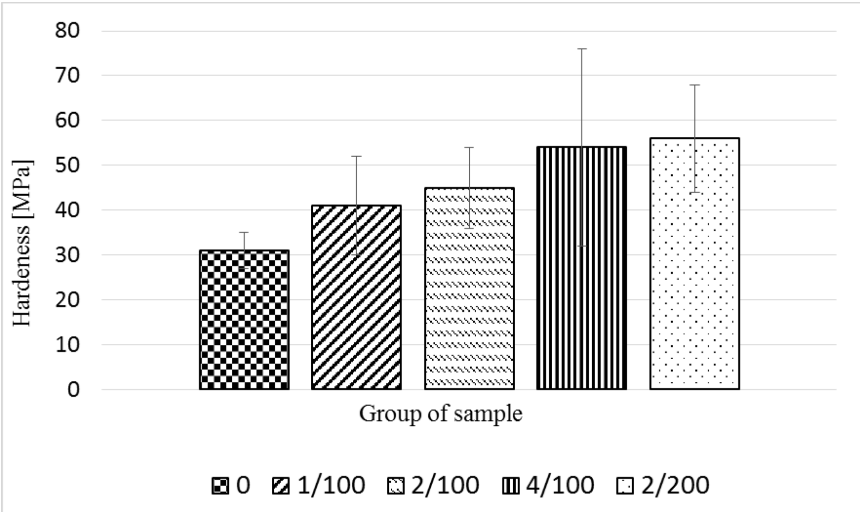


Fig. 2. Hardness of the modified surface

Contribution of Site Orientation to the Seasonal Fluctuations of Wood Moisture Content in Wooden Windows

Vjekoslav Živković[1], Hrvoje Turkulin[2], Dejan Purić

[1,2] Department for furniture and wood products, Faculty of forestry, University of Zagreb, Zagreb, Croatia, zivkovic@sumfak.hr

Keywords: gradient, moisture content, windows, wood

Introduction

Durability of wood windows is especially important issue in times when energy efficiency, natural resources management and carbon cycle of products have great value. It greatly depends on several important factors: material selection, physical protection and detailing, surface protection, installation and regular maintenance. Moisture content and its distribution over the cross section of window frames directly influences dimensional (in)stability, particularly bowing and distortion. Therefore, the scope of this work was to monitor the distribution of moisture content of wood windows during one year period in order to get detailed insight into the influence of site orientation to the risk of degradation of wood.

Materials and methods

Four different windows of the family house in continental Croatia were taken as a material for this research. Measurements were taken on several different windows placed on comparable positions of the family house facing east, west, north and south during one year period. All the windows were partially protected with the roof overhang, leaving their lower parts exposed to weathering. In order to get the insight into the moisture content distribution over the cross section of the frame, three pairs of electrodes with insulated shafts were used at each measuring position. MC was measured using electric resistance moisture meter, and exterior weather conditions data (air temperature, relative humidity, precipitation) were taken from the local meteo station. Interior conditions (temperature, relative humidity) were also regularly monitored.

Results and Conclusions

Comparison of the distribution of moisture content (MC) on 4 different windows on comparable positions facing east, west, north and south, placed 3 m above ground is performed in the corner of the lower window frame.

The results of the measurements in the *outer zone of the frame* (Figure 1) indicate that, during one year period, the lowest maximum moisture content was detected on the window facing south (14,5%), east (16,5%), west (19,5%) and the highest maximum was measured on the window facing north (21%). The maximum MC of wood materials in external windows as defined in EN 14220 should not exceed 15% in most European countries, and MC over 22% at 20 °C during the period longer than 2 weeks poses a great risk of biological infection. Based on the results presented here (Figure 1) it is evident that the windows facing north have MC over 15% already from early September until the first half of August, windows facing west have higher MC from mid September until late April, windows facing east reach 15% in December, and maintain such values until early April, whereas windows facing south never reach 15% MC at this measuring position. At the same time, windows facing north attained MC close to 20% from late autumn until spring.

Minimum MC values also differ significantly, depending on the side of exposure. The lowest minimum MC was detected on the window facing south (9%), east (10,5%), west (11,5%) and the highest minimum was measured on the window facing north (15%). The minimum MC of wood materials in external windows as defined in EN 14220 should not be below 11%. Only windows fully exposed to south exceeded that limit during late summer period.

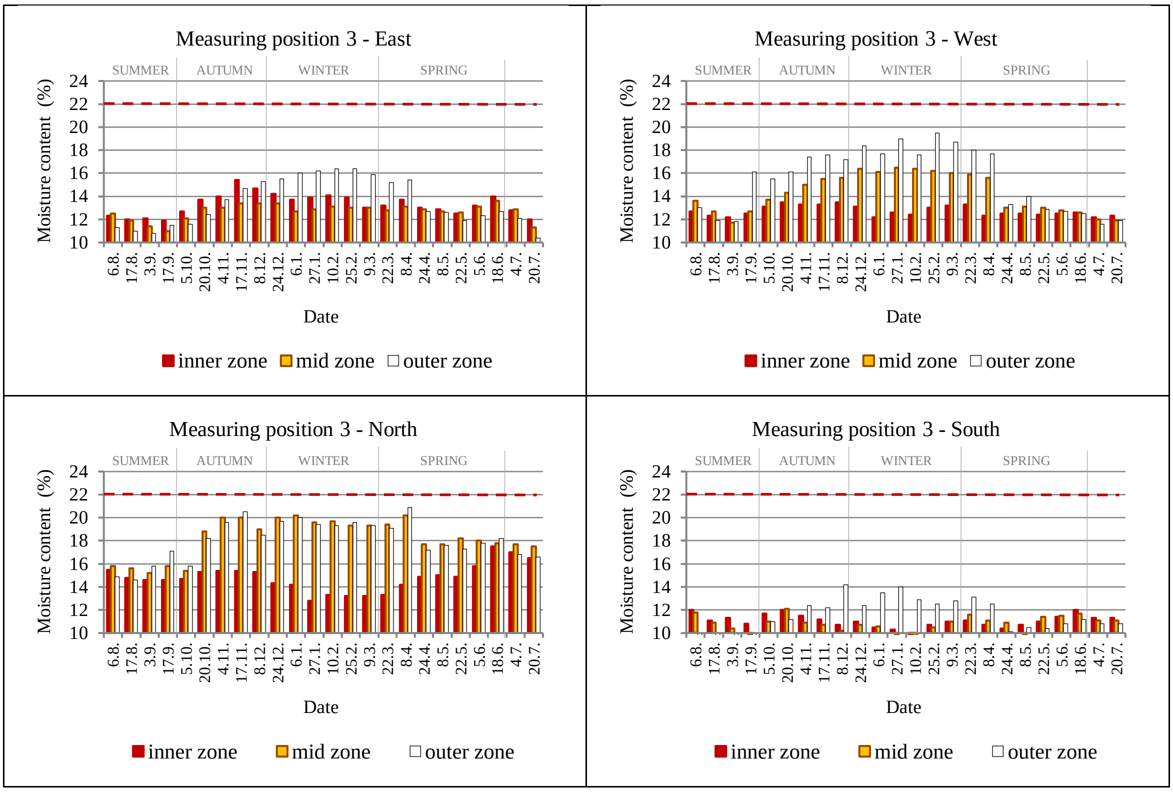


Figure 1: Influence of site orientation (east, west, north and south) to the seasonal fluctuations of wood moisture content in wooden windows measured on comparable position of the window frame

Moisture content values in *inner zone* are in much narrower range compared to the outer zone during monitoring period. The lowest and the most uniform MC values are measured in south position (10 - 12 %), and the highest and widest MC range was detected in north (13 - 17 %). The distribution of MC between the outer, mid and inner zone also depends on the exposure site, the lowest differences were measured in south and the greatest in the north side. The greatest differences (up to 6%) were detected during winter period. The smallest differences in MC (1 - 2 %) were detected in summer.

Provided that windows are installed and maintained properly, east, west and south exposition will always attain significantly lower moisture content compared to north side. This is mostly due to absence of direct sun in the north exposition which would facilitate the reduction of wood moisture content to the acceptable range.

Colour variation within the material of new *Robinia* varieties with high growing rates

Miklós Bak[1], Róbert Németh[2], Diána Csordós[3], László Tolvaj[4]

[1,2,3,4] University of Sopron; Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts; Hungary; [1] bak.miklos@nyme.hu; [2] nemeth.robert@nyme.hu; [3] diana.csordos@skk.nyme.hu; [4] tolvaj.laszlo@skk.nyme.hu

Keywords: heat treatment, OHT, color homogenization, beech, false heartwood

Black locust (*Robinia pseudoacacia* L.) is fast-growing, durable, malleable, ductile, and versatile. The tree is characterised by its richness of colour. Its sapwood is light yellow to light yellowish-brown, and its heartwood is greenish to yellowish brown. In the past, *Robinia* has been used mainly for firewood, rather than for visible structural elements (e.g., upholstered furniture frames). Today, it has become a valuable raw material for interior decoration. This radical change of perspective is caused by the various breeding procedures which make it possible to change the colour of mottled wood or homogenise its colour (Tolvaj et al. 2010). The fast-growing *Robinia* varieties achieved yields of up to 200% compared with the traditional varieties (Fig. 1). Based on previous mechanical and physical tests, they might become an important industrial raw material. The primary goal of our work was to display the colour variability of *Robinia* varieties (clones) with high growth rates. Increased growth rate achieved by the breeders are likely to affect the colour of the wood, which affects its interior use and interior design. In total, 26 strains of 10 different fast-growing *Robinia* varieties from six East Hungarian regions were investigated. In total, 4 strains of 3 different non-fast growing *Robinia* varieties served as the control (Table 1). Colour analysis was carried out according to the CIELab colour system. The measurement was made on the radial surfaces.

Figure 1: Control Robinia disc (Left, Variety code: O; Age: 20 years) and New Variety disc (Right, Variety code: A54; Age: 10 years)

Table 1: Basic data of the Samples

	Varieties code	Origin site numbers	Planted	Harvested	Number of samples	Strain diameter (mm)		Annual ring width (mm)	
						Mean	SD	Mean	SD
Fast growing varieties	A2	I; IV; V; VI	1985; 1995; 1997; 1999	2005	4	108.57	49.47	6.03	2.99
	A7	I; IV; V	1985; 1995; 1997	2005	3	108.94	53.26	6.05	2.61
	A32	I; III; V	1986; 1995; 1997	2005	3	113.63	10.43	5.88	2.70
	A33	I; III; V	1986; 1995; 1997	2005	3	106.67	21.82	5.93	3.07
	A54	I; III; V; VI	1986; 1995; 1997; 1999	2005	4	114.19	38.38	6.96	3.57
	B2	I; II	1997; 1999	2005	2	123.55	46.71	11.23	7.15
	B7	I; II	1997; 1999	2005	2	135.44	23.93	13.54	3.46
	B32	I; II	1997; 1999	2005	2	120.13	65.78	12.01	6.12
	B33	II	1999	2005	1	150.86	22.32	13.71	4.62
	B54	I; II	1997; 1999	2005	2	130.9	37.17	11.90	8.68
Control varieties	0	III; IV	1985; 1986	2005	2	101.19	49.78	3.99	1.63
	Ü	III	1986	2005	1	112.36	-	6.24	3.02
	NY	III	1986	2005	1	99.76	-	2.93	1.01

Standard deviation of the colour coordinate values is, in general, higher for fast-growing varieties. In addition, many outliers and extreme values of all colour coordinates could be observed, which is not typical of the control (non-fast-growing) varieties. However, there was an exception among the fast-growing varieties (A32), in which case none of the colour coordinates showed higher standard deviation compared to the non-fast-growing varieties (Fig. 2).

Figure 2: Typical samples of a control (O), a fast growing variety with low colour variation (A32), and two samples of fast growing varieties with high colour variation (B7 and B2)

There was no correlation between the mean annual ring width and the standard deviation of the colour coordinates. Namely, the higher colour variability is not primarily due to the higher growing rate. It is considered that when comparing the colour variability of the different varieties from the same growth sites, the higher standard deviation of the colour coordinates by the fast-growing varieties is a varietal, genetic characteristic. No significant differences were found among the different varieties in case of the mean colour coordinates. It is not possible to determine the applicability of the *Robinia* wood according to the mean colour values of the heartwood or sapwood, from an aesthetics viewpoint. It is necessary to investigate the standard deviation of the colour coordinates to show the colon variability and the applicability for aesthetical aspects of the different varieties.

References

Tolvaj L., Molnár S., Németh R., Varga D. 2010. Color modification of black locust depending on the steaming parameters. Wood Research 55(2): 81-88.

Possibilities to Use Modern Biobased Materials in Traditional Wooden Beam Floors

Anna Rozanska[1], Anna Policinska-Serwa[2],Wojciech Korycinski[3]

[1] Faculty of Wood Technology, Warsaw University of Life Sciences WULS-SGGW, Poland, annamaria.rozanska@gmail.com

[2] Building Research Institute, Warsaw, Poland, anna.serwa@gmail.com

[3] Department of Industrial and Medicinal Plants, University of Life Sciences in Lublin, Poland, wojciech@korycinski.pl

Keywords: antique wooden floor, biobased floor materials, floor reuse, beam floor

The main technological processes related to the installation of wooden floors consist in preparing the subfloor, placing the floor elements and fixing them to the subfloor and finishing the parquet surface, protecting it against destructive factors resulting from usage. Modern biobased materials can be used at every stage to successfully replace solid wood in reconstructed floors, as well as selected products used for antique floor conservation, whose application is justified by substantive reasons related to the protection of historical buildings or to the safety requirements protecting people inside such buildings.

The principles of protection of historical wooden structures defined in the ICOMOS IWC Charter (Mexico, 1999) stress the necessity of using traditional means (Art. 5), admitting however the possibility of replacement in case of decay or damage of structural elements or parts of the construction, or in line with restoration requirements, permitting contemporary materials or reinforcements. The criterion to admit modern biobased materials for conservation works in floors of historical buildings is based on the confirmed efficiency of materials and technologies, as well as the lack of negative impact on the technical, historical, artistic and aesthetical value of the antique object or structure. Therefore, this issue refers mostly to covered structural elements such as joists or the decking, contributing, to a large extent, to longer durability of wooden antique parquets, often having decorative character.

In view of the safety during further usage of historical wooden structures, the new materials introduced into them should meet the requirements of European construction standards [Rozanska et al. 2012, Policinska-Serwa et al.2016]. The joists and the remaining elements - such as binding joists and posts - have to be designed in accordance with the requirements of Eurocode 5 (EC 5). Structural elements can be made only of wood approved for construction applications, that is: coniferous wood (spruce, pine, fir or larch) that has been strength graded and has a defined strength class C 24. The wood has to be marked with the CE mark and should fulfill the requirements of the EN 14081 standard. Considering that in construction practice joists should be made of impermeable or impregnated materials, apart from the most popular solid pine, joists made of plywood strips or OSB boards fixed to the subfloor are also used. These materials do not require additional impregnation with biocides.

The decking - so called blind floor - is fixed to a structure made of beams. Traditionally, decking was made of solid wood planks that nowadays are often replaced with OSB 3 or 4 in conservation. The use of OSB panels can be justified by the need to level the surface in floors exposed to intense pedestrian traffic and highly variable dynamic loads caused by the foreseeable manner of usage. The thickness of planks as well as the amount and type of joints have to result from calculations, in line with the EN 1991-1-1 standard, or tests carried out in accordance with EN 1195 and EN 12871 standards. Planks require a large number of joints and tend to bend and curl, which is why in conservation works they are often replaced with engineered wood boards in the decking, provided that they meet the requirements of the EN 13986 standard, have the CE mark and are specifically dedicated for construction applications in floor decking - which has to be specified in the usage property declaration and usually also indicated by a special mark on the board - the word "floors". In case of decking made of OSB 3 panels it is necessary that the longer edges of the boards be supported by joists and connected above their axis, with expansion joints between adjacent boards of at least 2-3 mm. If the floor is intensly used during conservation works, two layers of OSB 3 panels are used, each at least 11 mm thick, overlapping one another as far as joints are concerned, but respecting the rule of connections placed over joists and expansion joints in each layer. Additionally, panels with profiled connections can be applied (working with a so called bigger surface, which eliminates local deviations from the horizontal plane that tend to cause damage to parquets).

The span between joists is defined both for decking made of planks and engineered wood boards, and in both cases it depends on the decking thickness. A manual published in the 1930s recommended to place joists every 450 mm if the blind floor made of planks was 25 mm thick; every 650 mm if the planks were 33 mm thick; and 800 mm in case of planks that were 38 mm thick [Mielnicki 1938]. The span between joists recommended for OSB panels is more favourable and amounts to 400 mm for 15-18 mm thick OSB, 500 mm for 18-22 mm thick OSB, and 600 mm for OSBs over 22 mm.

In conservation works, it is recommended to use traditional wood surface finishes - oil or wax. A good solution consists of contemporary parquet oil that can be additionally finished with wax oil. Linseed varnish darkens the wood surface too much, while the application of hot wax is troublesome and requires adequate qualifications. Contemporary parquet oils dry easily and have a pleasant smell, while their resistance to abrasion and scratches is comparable with antique finishes [Rozanska et al. 2013].

References

Policińska-Serwa A., Rozanska A. 2016. Methods and possibilities for conservation of antique wooden floor in the light of current construction standards. Annals of WULS, 96: 107-114

Rozanska A., Burawska I., Policińska-Serwa A., Koryciński W., Mazurek A., Beer P., Swaczyna I. 2012. Study of antique wooden floor elements of chosen buildings from south-eastern Poland. Proceeding of the *8th International Conference on Structural Analysis of Historical Construction SAHC 2012*, 15-17 October 2012, Wroclaw Poland: 905-913

Rozanska A., Korycinski W., Kowaluk G., Beer P. 2013. Influence of wooden floor surface finish on its hardness, resistance to abrasion and resistance to scratches. *Annals of WULS- SGGW*, 84: 97-115.

Passive indoor conditioning of grocery stores with interior application of wood

Kristine Nore[1], Petter Arnestad[2], Anders Q. Nyrud[3]

[1] Norwegian Institute of Wood Technology, PB 113 Blindern, 0341 Oslo, Norway, Kristine.nore@treteknisk.no

[2] greenretail, PB 289 Skøyen, 0213 Oslo, Norway, pa@greenretail.no

[3] Norwegian Institute of Wood Technology, PB 113 Blindern, 0341 Oslo, Norway, ander.q.nyrud@treteknisk.no

Keywords: Indoor climate, hygroscopic materials, buffering capacity, energy saving, substitute material

Climate neutral grocery shopping is a goal that implies turning every stone to also minimize the CO_2 footprint of the grocery store. In Norway, several leading food retailers have included wood as a part of their search for optimal climate solutions.

The climate in grocery stores is influenced by several factors, among other things internal factors that originate from the inside of the building. These internal factors include large amounts of surplus heat and areas of potential condensation and water spills from cooling equipment. Condensation occurs especially when fresh foods that hydrate moisture are exposed to temperature drops in cooling and freezing zones. Additionally, the air temperature inside the grocery store has to be limited to 27°C to prevent goods from melting. At the same time, customers expect comfortable indoor climate, and employees demand a safe and pleasant work environment. Conditioning spaces requires in addition to temperature management, control of ambient and local relative humidity and emissions.

Careful management of the internal factors is essential and hygroscopic materials can play an important role as they buffer humidity and energy. The buffer capacity of wood fits well with the climate conditions inside a grocery store. Wood mainly contributes to humidity buffering, but at the same time reduces the need for cooling and heating significantly. The term hygrothermal mass is defined to explain this potential effect of wood, see Figure 1. The use of wood in structural and interior application of grocery stores is estimated to save about 20 000 kWh per year compared to a conventional grocery store.

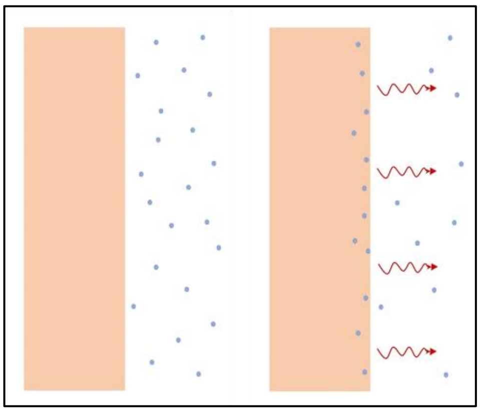


Fig 1. Sorption heat from wood can counterbalance fraction of the heat losses Thus a potential for energy savings is provided, defined as hygrothermal mass.

Building with wood requires awareness of possible risks related to moisture, but also the potential to lower the operating cost of buildings by integrating the beneficial properties of wood. The positive potential of moisture buffering has hardly been studied and not found used deliberately in grocery stores by the authors. The current poster describes results obtained in an environmental friendly grocery store opened in 2016. Figure 2 shows the measurement set up at Kiwi Fjeldset, at Elverum in Norway. The logging has been ongoing since February 2016. In addition to normal supermarket climate control wood weight, temperature, ambient air humidity and temperature is measured.

In addition to its buffering capacity, wood is a CO_2-efficient substitute for other building material. It lowers the CO_2 spill in any new build or renovation project. To display the substitution effect of wood, three grocery stores with extensive use of wood materials in the building construction are compared to traditionally built stores.

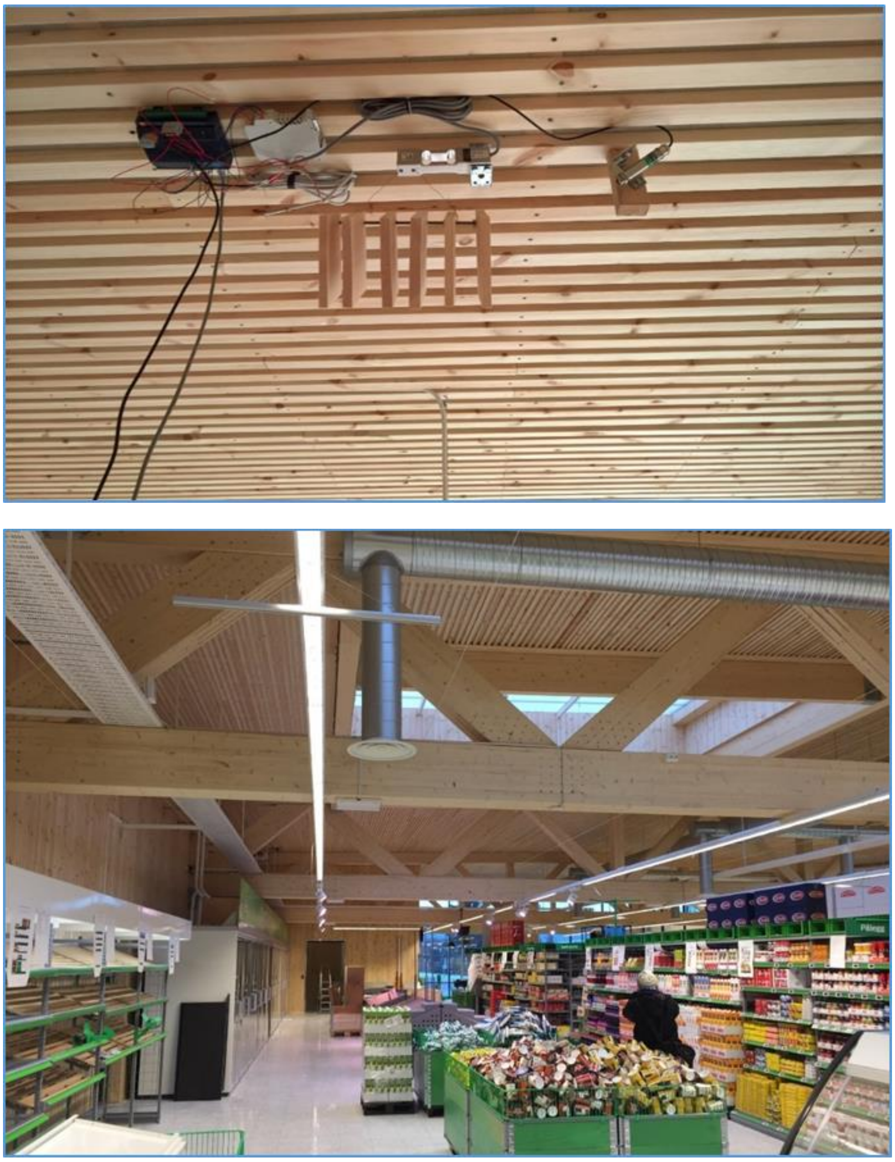


Fig 2. Set up to measure potential hygrothermal mass is measured in the supermarket Kiwi in Elverum, Norway.

MDF Recovery: Recycled MDF technologies for routed and laminated applications.

Simon Curling[1], Rob M. Elias [2], Graham A. Ormondroyd[3]

[1] BioComposites Centre, Bangor University, Bangor, Gwynedd, United Kingdom LL572UW. s.curling@bangor.ac.uk

[2] BioComposites Centre, Bangor University, Bangor, Gwynedd, United Kingdom LL572UW. r.m.Elais@bangor.ac.uk

[3] BioComposites Centre, Bangor University, Bangor, Gwynedd, United Kingdom LL572UW. g.ormondroyd@bangor.ac.uk; Department of Architecture and Civil Engineering, University of Bath, Claverton Down, Bath, UK,

Keywords: Panel Products, Recycling, Lamination, Colour

Medium Density Fibreboard (MDF) is an engineered wood panel product composed of refined virgin wood fibres, mixed with resin and wax and pressed into flat sheets under pressure and at elevated temperature. It is mostly used for furniture production and, like plywood, as a building material. It is often confused with particleboard, but MDF is far easier to handle with industrial machinery and it has a smooth surface that is ideal for applying surface finishes or paint.

Approximately 1 million tons of MDF are used in the UK every year, 13 million tons in Europe and 25 million tons worldwide. The material has been embedded into furniture, shop fittings and joinery products for over 40 years and so extensive volumes of post consumer waste will need to be processed in the coming years. In a report the Waste and Resources Action Programme (WRAP) (2009) stated that conservative estimates suggested over 150,000 tons of MDF waste from the UK furniture sector alone were either disposed of in landfill sites or burnt without energy recovery.

MDF recovery and the BioComposties Centre have developed an innovative technology to reprocess medium density fibreboard (MDF). The process now developed consists of a wet phase, grading of the waste, mechanical dewatering, flash drying and finally decontamination.

Recent work has shown that panels made with a proportion of rMDF fibre do not exhibit major colour differences from those made with 0% rMDF and therefore the panels will accept lamination without any bleed through of colour (figure 1). It has also been demonstrated that the MDF can be profiled with a router as well as virgin MDF.

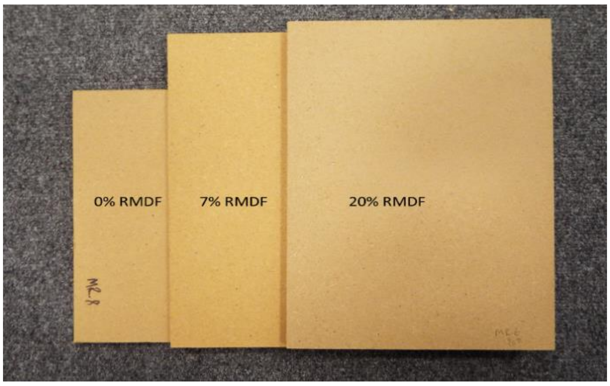


Figure 1: Panels manufactured with different additions of rMDF fibre

References

WRAP (2009) *Demonstration of end uses of recovered MDF fibre* http://www.mdfrecovery.co.uk/wordpress/wp-content/uploads/2015/02/WRAP-MDF_Recycling_-_demonstration_of_end_uses.pdf [Accessed 10/1/17]

Acknowledgments:

The authors would like to acknowledge Innovate UK for the funding of project 101895 'MDF Enhancing Supply Chain Value' and Mr N. Laflin and Mr J Nichols for their contributions to the project.

Durability testing of a Cattail (*Typha* spp.) based insulation material against termite attack

Unger, Wibke [1] and Thomas L. Woods [2]

[1] University of Applied Sciences Potsdam, Germany, wibke.unger@fh-potsdam.de
[2] Wood Preservation Consultant, Granville, New York, U.S.A.

Keywords: Insulation, termite, Cattail, *Reticulitermes*, methodology

Abstract

The use of insulating materials is particularly important in the construction industries, particularly with regard to the use of wood and naturally occurring substances. The use and durability of natural materials as insulating materials is of keen interest to many construction experts, and continues to be a topic of intense investigation. It is generally agreed that the use of natural substances as insulation is possible if certain harmful influences are prevented or controlled. We investigated plant material of the cattail (*Typha spp.*) which consists of long, tear-resistant fibers and a compressible sponge-like tissue. The test material has a low specific density of 0.65 kg / m³. Test specimens consist of insulating panels which would typically be used in walls and roofing areas, as well as inside living areas.

It is especially desirable that the cattail-based insulating material be suitable for use in tropical environments where the insect and decay hazard is more severe than in temperate climates.

In our research, we examined the resistance of a cattail-based insulation material against destruction by termites. Objectives of the testing were to determine resistance against termites and to assign a durability class to the test material.

The experiments are in accordance with the European standard EN 117 and EN 118. The termite species *Reticulitermes santonensis* de Feytaud is the test organism. The test specimens have dimensions of 50 x 25 x 15 mm, and the test duration is 56 days. The test arrangement includes three different variations: the Forcetest is a test with only one specimen in a vessel; the Choicetest includes two specimens; and the Controltest demonstrates the behavior of termites under optimal conditions.

The test results are discussed with emphasis on the possible use of cattail-based insulation material in tropical countries where the termite hazard is of particular importance.

Time-variant Reliability of a timber truss subjected to decay considering humidity and temperature climate change

Y Aoues[1], E. Bastidas-Arteaga[2], Y. I. Teodorescu[3]

[1] Normandie Univ, INSA Rouen Normandie, France younes.aoues@insa-rouen.fr

[2] University of Nantes, Nantes, France emilio.bastidas@univ-nantes.fr

[3] Technical University of Civil Engineering Bucharest, Bucarest, Romania
ioanatd@yahoo.com

Keywords: Reliability, timber, truss, probability of failure, humidity, temperature

Introduction

The assessment of reliability of existing timber truss subjected to degradation is an important task for taking decisions on inspection, maintenance and repair actions (Brites et al., 2013). Several kinds of uncertainties related to wood properties, structural dimensions, and load fluctuations are involved. Furthermore, the mechanical properties of timber structures over the time are affected by a combination of loading, moisture content, temperature and biological activity. The design of timber structures considers these uncertainties through the use of prescribed partial safety factors recommended in the code of practice as Eurocodes 5. The use of these partial safety factors in designing new timber structures generally leads to safe structures. Nevertheless, the timber resistance capacity is affected by the load duration, moisture content and biological activity. The exposition of the unprotected timber truss to high relative humidity exposure and high moisture content of wood can lead to bio-deterioration of timber with decay fungi. This deterioration reduces the strength capacity of timber structures. Unfortunately, the decay deterioration of the wood material is not appropriately taken into account in the calibration of the partial safety factors.

In order to overcome these limitations, the reliability analysis can be used to assess the safety of existing timber structures with including the effects of decay on structural safety. This study proposes the use of the time-variant reliability approach to analysis the safety of the timber truss subjected to decay degradation under various climate change scenarios. The time-variant reliability aims at computing the probability of failure during the whole structure lifetime, when the time dependency lies in the loading and the degradation phenomena. Where the load and the climate parameters (temperature and relative humidity) are usually randomly varying in time and should be modelled by random processes (Andrieu et al. 2002).

Results

The deterioration processes and the structural behavior of timber structures are complex, nowadays the deterioration models are not able to account for all influencing factors. Consequently, this study is based on an empirical model that was derived on the basis of previous in-lab experimental studies, Viitanen et al., (2010) developed a model for the decay growth of brown rot in pine sapwood under variant climate conditions. Figure 1a) presents the random process trajectories of humidity and temperature considered as major parameters of the climate changes. Figure 2b) present the profile of the reliability index of the Ultimate (ULS) and the Service Limit states (SLS). These results reveal that for the first scenario of the climate change the ULS and SLS limit states verify the target reliability levels. In the second scenario the reliability index of these limit states is below the target reliability levels.

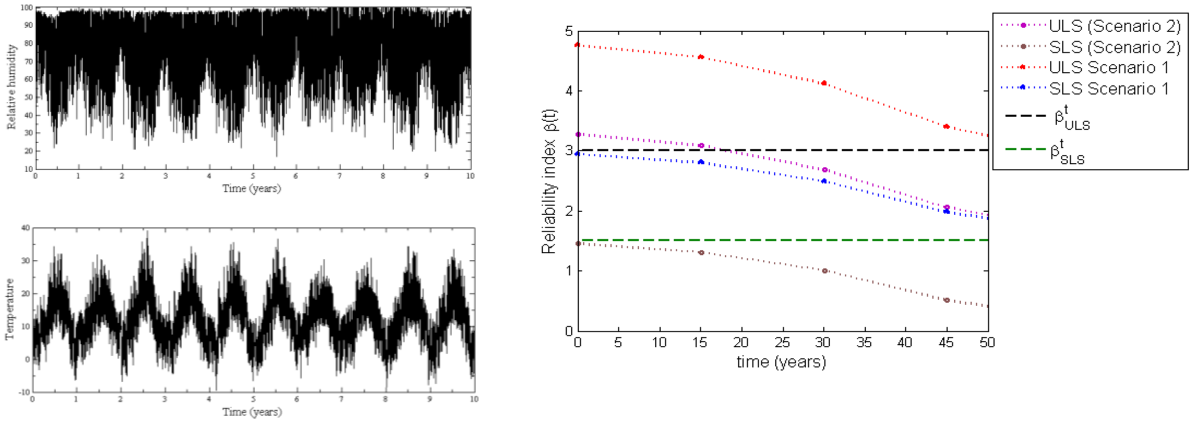


Figure 1. (a) Temperature and relative humidity random process ; (b) The time-variant reliability index profile for Ultimate (ULS) and Service (SLS) Limit States

Conclusions

This study proposes the use of e time-variant reliability approach to predict the probability of failure of timber truss element members under biological degradation and climate changes, function of temperature and humidity. The structural lifetime of timber trusses depends on the relative humidity in different combinations with temperature and exposure time. Together, these factors can deteriorate the material by developing mold surfaces.

References

Andrieu-Renaud, C., Sudret, B., and Lemaire, M. The PHI2 method: a way to compute time-variant reliability. Reliability Engineering and System Safety.,2004;84(1): 75-86.

Brites, R.D., Neves, L.C., Machado J.S., Lourenço P.B., Sousa .H.S. Reliability analysis of a timber truss system subjected to decay. Engineering Structures, 2013; 46:184-192.

Viitanen, H., Toratti, T., Makkonen, L., Peuhkuri, R., Ojanen, T., Ruokolainen, L., Räisänen, J. Towards modelling of decay risk of wooden materials. Eur. J. Wood Wood Prod. 68, 303–313.

Acknowledgments

The authors would like to acknowledge the financial support of project CLIMBOIS ANR-13-JS09-0003-01 as well as the labelling of the ViaMéca French cluster.

Environmental impact on crack propagation of biobased building materials: application to *Abies Alba* Mil

Claude Feldman Pambou Nziengui[1, 2,3], Rostand Moutou Pitti[2, 3,4], Éric Fournely[2, 3]

[1] ENEF, BP 3960 Libreville, Gabon, pclaudefeldman@gmail.com

[2] Clermont Université, IOP, BP 10448, 63000 Clermont-Ferrand, France, rostand.moutou_pitti@univ-bpclermont.fr

[3] CNRS, UMR 6602, IP, F-63171 Aubière, France, eric.fournely@univ-bpclermont.fr

[4] CENAREST, IRT, BP 14070 Libreville, Gabon

Keywords: Crack, Environmental effects, Creep tests, *Abies Alba* Mil

One of the main objective of French ANR project CLIMBOIS N° ANR-13-JS09-0003-01, is to know the impact of climatic variations on the behaviour of timber structures. To reach this goal some tests are performed on notched beams of European species. This work presents the first experimental results of creep test carried out on a notched beam of *Abies Alba* Mil.

Material and Methods

According to European code Eurocode 5, a notched beam of *Abies Alba* Mil has been dimensioned as presented on figure 1a. Then, the beam is submitted de environmental effects coupled with creep loadings induced by a four points bending during 5 days until the total collapse, Figure 1b. During the test, there appeared cracks at the right of the notches on the four faces of the beam, a daily follow-up of the opening and propagation of the tips of cracks versus the climatic parameters (Temperature, HR) is carried out.

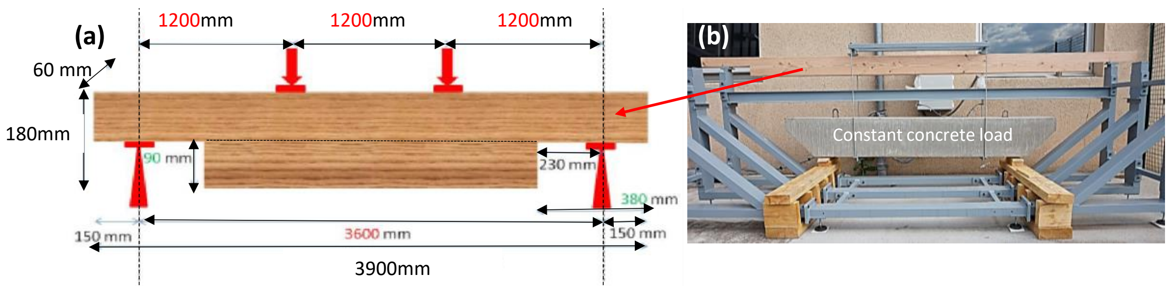
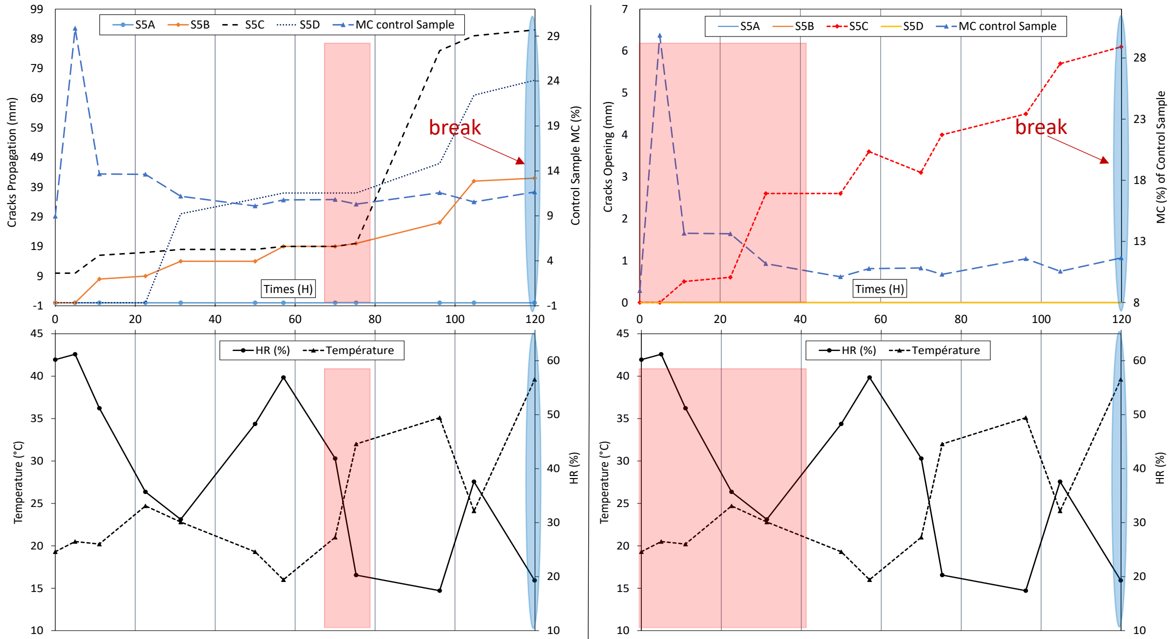


Figure 1: Scheme of notched beam tested (a). Real experimental devices (b).

Results

Figure 2a shows the propagation of the tips of cracks of the four faces versus the climatic parameters (Temperature T, Relative Humidity HR). Between the times 70-80H there are a pronounced impact of T and HR on the propagation of the tips of cracks. Figure 2b shows also the influence of T and HR on the opening of crack during the test and before is break. We can remark that there is a correlation between the opening of crack and the augmentation or the diminution of T and HR (figure 2b, 0-40H). These experimental results (Figure 2) are in an accordance with the results obtained by (Pambou *et al*. 2016) on the *Pseudotsuga menziesii* J.L. The evolution of the deflexion versus environmental parameters will be investigated in the coming works.



(a) Cracks propagation Vs. Climatic variations

(b) Cracks opening Vs. Climatic variations

Figure 1: Propagation of cracks versus climatic parameters (T, HR).

References

Pambou Nziengui C. F., Moutou Pitti R., Fournely E. *et al.* 2016. Projet ANR JCJC CLIMBOIS: impact des conditions climatiques sur la propagation de fissure de poutres de Douglas en fluage extérieur. 5ièmes journées du GDR 3544 ”sciences du bois”- Bordeaux, 8-10 novembre 2016.

Acknowledgments:

The authors would like to acknowledge the national agency of Gabon scholarships (ANBG), the National Agency of Research (ANR) for theirs financial supports of this work through the project CLIMBOIS ANR-13-JS09-0003-01 as well as the labelling of the ViaMéca French cluster.

Emissions from bio-based building products

L. Clauder[1], E. Mansour[2], G. Ormondroyd[2], A. Pfriem[1]

[1] Eberswalde University for Sustainable Development, Germany,
Lothar.Clauder@hnee.de, Alexander.Pfriem@hnee.de

[2] BioComposites Centre, Bangor University, United Kingdom,
g.ormondroyd@bangor.ac.uk, e.mansour@bangor.ac.uk

Keywords: corrosion, emissions, volatile organic compounds

The study focused on the emission behaviour of wood and the occurrence of corrosion on lead coupons due to these emissions when both materials were combined in a modified Oddy test (Oddy 1973, modified). Wood may not seem like a challenging environment for corrosion but by its porous micro- and ultrastructure wood has complex interactions with water that greatly affects its physical, mechanical, and chemical properties, including corrosion (Zelinka 2014). Wood can be considered as one of the major emission sources of formaldehyde and other volatile compounds. During the kiln drying of wood, the hydrolysis of cell wall components (cellulose, hemicellulose and lignin) leads to formation of furfural, formaldehyde and very volatile acids, e.g. acetic and formic acid. In addition, at a relative humidity of 20 % an initial molecular layer of water on the metal surface can react with atmospheric formaldehyde to produce formic acid which in turn causes metal corrosion (Hatchfield et al. 1986).

The selected test set up consisted of wood species which are known to have low emissions such as Alder, and wood species with expected higher emission rates such as Ash and Oak. Six samples of each species were impregnated with a buffer-solution and were dried under vacuum conditions along with further six untreated samples to an absolute dry state. According to Cole (1979) a pH range of 3.3 to 7.2 for hardwoods (e.g. 5.5 for Alder and 3.3 to 3.9 for Oak) was found. All pH measurements were made with a WTW pH meter, Model inoLab according to the technique of Lambuth (1967). In this study the measurements of the emissions from wood were performed based on ISO 16000-10 (2006) with a micro-chamber. Specimens were installed under constant conditions with respect to temperature, relative humidity and air exchange rates. The samples were prepared according to ISO 16000-11, formatted (Ø 40 mm) and stored in a conditioning room (23 ± 2 °C and 50 ± 5 %). Prior to the tests, fresh surfaces were planed. The stainless steel cell allowed a controlled climate at 23 ± 1 °C and 50 ± 3 % RH. Using the Oddy test (Oddy 1973), potential damage of art objects through formaldehyde and organic acid (formic and acetic) vapour is seen to accelerate by the addition of a small amount of water (1 ml), elevation of temperature to 60 °C and storage for 28 days; this prompts the evolution of potentially corrosive gases from the test material and metal corrosion reactions.

The impregnation with the buffer solution led to the intended effect. The results showed that the buffer system with a pH value of 7.2 caused an increase of the pH values of the three different species: Alder (6.22 to 6.65), Oak 4.72 to 5.27) and Ash (5.82 to 6.82). The subsequently performed investigations of the emissions and the degree of corrosiveness were affected by the decreased acidity of the specimens (Fig. 1).

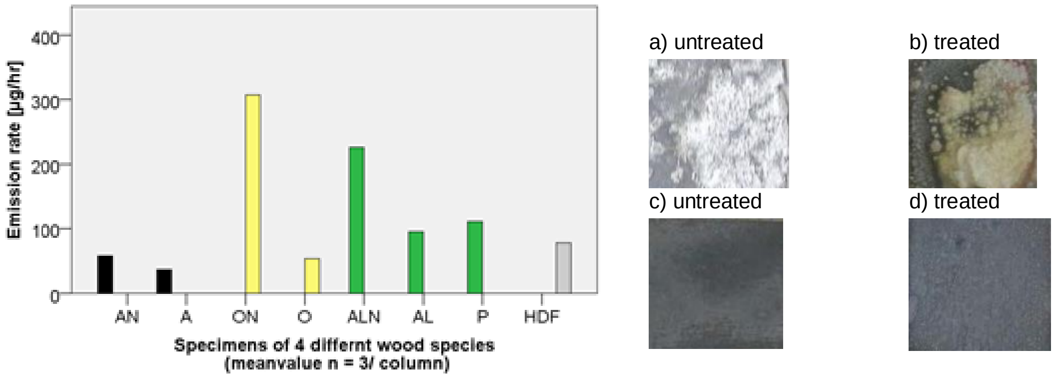


Figure 1: left: Sum of emissions of aldehydes consisting of C>2 (i.e. furfural, hexanal, heptanal, octanal, nonanal and decanal) AN = Ash untreated, A = Ash impreg., ON = Oak ut, O = Oak i., ALN = Alder ut, AL = Alder i.; right: lead coupons removed from Oddy test-vessel

The results indicated the positive influence of the buffer treatment on the chemical compounds. However, acet-, formaldehyde and VOCs possess very little corrosiveness towards materials like textiles, paper and metals. By contrast, vapours of organic acids (formic and acetic acid) are known to be reactants in the metal corrosion. This became visible after the Oddy tests when lead coupons were removed from the test vessels. Due to increased amounts of water available in the vessel, the results became more pronounced to the point of being rated as unsuitable because of heavy corrosions. Possibly usage of biobased products is limited in sensitive environment.

References

Cole, H.C., Chandler, K.A., Bernie, J.A., Leach, L., Parkins, R.N., Pequinot, C.A., Shrier, L., Smith, T.J. (1979): Guides to practice in Corrosion Control, Corrosion of metals by wood, Corrosion Centre Wales, Newport, Wales.

Hatchfield, P.B., Carpenter, J.M. (1986): The problem of formaldehyde in museum collections, In: International Journal of Museum Management and Curatorship, 5 (2), pp. 183- 188, DOI: 10.1080/09647778609515020

Lambuth, A.L. (1967): Procedure for determining the pH and buffering capacity of wood. Lab Test Method No. 142, Monsanto Company Seattle Research.

Oddy, W.A. (1973): An unsuspected danger in display, In: Museums journal 73, pp. 27-28.

ISO 16000 (2006): Indoor air Determination of the emission of volatile organic compounds from building products and furnishing - Part 10: Emission test cell method, Part 10: Sampling, storage of samples and preparation of test specimens.

Zelinka, S., Glass, V., Stone, D. (2008): A percolation model for electrical conduction in wood with implications for wood-water relations. In: Wood and Fiber Science 40(4), pp. 544-552.

Acknowledgments: The authors gratefully acknowledge the financial support of the COST action FP1303 for the STSM.

Functional properties of wooden surfaces in real indoor environments

Katja Vahtikari[1], Yrsa Cronhjort[2,] Ira Verma[3], Mark Hughes[4,]

[1] P.O.Box 16300, FI-00076 Aalto, Finland, Aalto University School of Chemical Technology, katja.vahtikari@aalto.fi

[2] P.O.Box 16500, FI-00076 Aalto, Finland, Aalto University School of Arts, Design and Architecture, yrsa.cronhjort@aalto.fi

[3] P.O.Box 16500, FI-00076 Aalto, Finland, Aalto University School of Arts, Design and Architecture, ira.verma@aalto.fi

[4] P.O.Box 16300, FI-00076 Aalto, Finland, Aalto University School of Chemical Technology, mark.hughes@aalto.fi

Keywords: wooden surfaces, user requirements, cleanability, moisture buffering, interior design

Project *Competitive wood-based interior materials and systems for modern wood construction,* Wood2New, has explored the use of wood in interiors from various perspectives. The scope of work included technical material properties like hygrothermal and moisture buffering capacity of wood material (Kraniotis et al. 2016), and emissions of Volatile Organic Compounds (VOC) (Weigl et al. 2016), but also intangible aspects of material use like end-user perceptions of wood material and built environments (Cronhjort et al. 2017).

Research has shown that wooden surfaces can moderate humidity fluctuations of indoor air, but these functional properties of wooden surfaces are not yet widely exploited in the indoor environment. This paper shows examples of interiors with varying amounts of exposed wood and discusses the possible potential of various wooden solutions and coatings.

Figure 1 shows an overall image of selected spaces. Case examples include meeting rooms and care environments used in the study of Cronhjort et al. (2017). Their careful collection of background information of the spaces provides information for the assessment of a more functional use of wood in discussed spaces. In many real cases the functional properties of wood are not fully utilized. Studies have shown that coatings decrease for example the moisture buffering capacity of wood material significantly (Vahtikari et al. 2016), but this seldom affects the choice of coating materials (Paloheimo 2008). Coatings are important factor also regarding the cĺeanability of wooden surfaces which is of importance for many people as the recent surveys show (Cronhjort et al.; Mace et al. 2107).

Figure 1: Overall image of the case examples. Images: Ira Verma, Laura Zubillaga, Janne Pihlajaniemi and Tomi Tulamo.

References

Cronhjort Y., Tulamo T., Verma I., Zubillaga L 2017. Interior design and care environments - End-user Perceptions of Wood Material. Technical project report. 70p. www.wood2new.org

Kraniotis D, Langouet N, Orskaug T, Nore K, Glasø G (2016). Moisture buffering and latent heat sorption phenomena of a wood-based insulating sandwich panel. In: Eberhardsteiner J, Winter W, Fadai A, Pöll M 2016, World Conference on Timber Engineering (WCTE 2016) August 22-25, 2016, Vienna, Austria.

Macé E., Taylor S., Vivien T., Suttie E. 2017. Space and End-user Requirements, Past and Future. Technical project report. 43 pages. www.wood2new.org

Paloheimo J. 2008. Multifunctional properties of wood adding value in potential interior applications. Master’s Thesis. Helsinki University of Technology, Espoo, Finland.

Vahtikari K, Noponen T, Hughes M (2016). The effect of wood anatomy and coatings on the moisture buffering performance of wooden surfaces. In: Eberhardsteiner J, Winter W, Fadai A, Pöll M 2016, World Conference on Timber Engineering (WCTE 2016) August 22-25, 2016, Vienna, Austria

Weigl M, Stratev D, Fürhapper C, Habla E, Nohava M, Niedermayer S (2016). Wood borne emissions in a real room environment- a modelling approach. In: Eberhardsteiner J, Winter W, Fadai A, Pöll M 2016, World Conference on Timber Engineering (WCTE 2016) August 22-25, 2016, Vienna, Austria.

Acknowledgments:

The research leading to these results is part of project Competitive wood-based interior materials and systems for modern wood construction, Wood2New, and has received funding from the WoodWisdom-Net Research Programme which is a transnational R&D programme jointly funded by national funding organisations within the framework of the ERA-NET Plus Action WoodWisdom-Net+.

The use of NIR spectroscopy as a quality marker of hydrothermally treated wood

Charalampos Lykidis[1], Jakub Sandak[2], Anna Sandak[2]

[1] Institute of Mediterranean Forest Ecosystems and Forest Products Technology, Terma Alkmanos, 11528, Athens, Greece, lykidis@fria.gr

[2] Trees and Timber Research Institute CNR-IVALSA Via Biasi 75, 38010 San Michele All'Adige (TN), Italy, sandak@ivalsa.cnr.it

Keywords: wood, hydrothermal treatment, NIR spectroscopy

Fast, non-destructive and efficient markers are currently required in the field of wood modification industry in order to be used for the estimation of the thermal treatment degree of wood (Willems *et al.* 2015). Spectroscopic methods were proved as valuable tools for non-destructive determination of many wood properties (Sandak *et al.* 2016). Hardness, mass loss as well as surface elasticity are physical properties that can be determined with minimal impact on wood and could also be used as markers of the thermal modification degree (Willems *et al.* 2015). Purpose of this collaboration was to evaluate the potential of NIR spectroscopy for non-destructive evaluation of hydrothermally treated wood. Beside of NIR, also other spectroscopic techniques were tested within this collaboration. The main steps of the research are presented along with some indicative results, since the data processing and analysis are still ongoing.

Beech (*Fagus sylvatica* L.) specimens with dimensions of 40mm x 40mm x 22mm were produced from defect-free sapwood. In order to facilitate comparison between treated and non treated wood, the specimens were cut in adjacent pairs, as explained in other works (Hansson and Antti 2006). Consequently half of the specimens were hydrothermally treated in a closed system using saturated steam at 110, 140, 170 and 200°C for intervals of 10, 30, 60, 120 and 240min. 5 specimens per treatment were used. All specimens were then conditioned in a constant climate of 65RH/20°C and used for the determination of Brinell hardness, surface elasticity. Hardness and surface elasticity were determined according to methods used by Niemz and Stübi (2000) and Rautkari *et al.* (2011). Spectra were acquired by using FT-NIR VECTOR 22-N (Bruker Optics GmBH) at 5 spots over each sample surface; four around corners of the sample surface containing the indentation mark of and one directly on the indentation area. A dedicated sample holder was constructed in order to assure measurements on the corresponding regions of both treated and reference specimens. The same procedure was performed on the respective paired samples and comparative spectra corresponding to treated and non-treated wood were acquired. The spectral range measured was between 4000cm^{-1} and 12000cm^{-1}. Halogen lamp served as the source of infrared light. The system was able to measure the spectra with a resolution of 8cm^{-1} and each spectrum has been computed as an average of 32 successive scans, in order to reduce the measurement error. All measurements were performed in the same climate conditions (climatic chamber 65RH/20°C.) In addition to the above measurements, FT-IR (in reflectance mode), UV-VIS (with probe and with integrating sphere) as well as custom made hyperspectral imaging system were used in order to acquire complementary information.

Spectra were preprocessed (extended multiplicative scatter correction) for multivariate analysis. Various chemometric methods were implemented for data analysis and mining. These included Principal Components Analysis, Partial Least Squares, 2D spectral correlation, among others. Particularly, PLS modeling was utilized to develop models predicting hardness, surface elasticity and mass loss change on the base of NIR spectra. The possibility for developing quality control routines based on NIR spectroscopy was also explored.

From the up to now analysis of the data very promising results came up concerning the correlation of treatment conditions against hardness, surface elasticity and mass loss. Multiple Linear Regression (MLR) analysis showed strong correlation of the predicted against the reference values. The results will facilitate better understanding of the degree of wood thermal modification. Proposed non-destructive methods might be used for on-line process control and for further optimization of the thermal treatment. It is expected that developed quality markers might assure well-defined improvement of material properties and contribute to the estimation of overall performance of wood as a building component. It should be clearly noted that due to the large volume of data acquired the analysis are still ongoing. The outcomes presented in this paper are only a small indicative part of the results that will come up upon completion of the analysis using all methods for all reference and estimated parameters.

References

Hansson, L., Antti, A.L. , 2006. The effect of drying method and temperature level on the hardness of wood. Journal of Materials Processing Technology, 171, 3:467-470.

Niemz, P., Stübi, T., 2000. Investigations of hardness measurements on wood based materials using a new universal measurement system. In: Proceedings of the symposium on wood machining, properties of wood and wood composites related to wood machining, Vienna, Austria pp. 51-61.

Rautkari, L., Kamke, F.A., Hughes, M. 2011. Density profile relation to hardness of viscoelastic thermal compressed (VTC) wood composite. Wood Science and Technology 45, 4: 693-705.

Sandak, A., Sandak, J., Allegretti, O. 2015. Quality control of vacuum thermally modified wood with near infrared spectroscopy. Vacuum 114: 44-48.

Sandak, J., Sandak, A., Meder, R.2016. Assessing trees, wood and derived products with near infrared spectroscopy: Hints and tips. Journal of Near Infrared Spectroscopy, 24, 6: 485-505.

Willems, W., Lykidis, C., Altgen, M., Clauder, L. 2015. Quality control methods for thermally modified wood: COST action FP0904 2010-2014: Thermo-hydro-mechanical wood behaviour and processing. Holzforschung, 69, 7: 875-884.

Acknowledgments

The support of COST FP1303 for funding the Short Term Scientific Mission of Dr. Charalampos Lykidis to CNR/IVALSA is greatly acknowledged. Part of this work has been conducted within the project BIO4ever funded within a call SIR by MIUR (RBSI14Y7Y4).

Bringing nature into workspaces: Employees' perceptions of their offices

Marko Posavčević[1], Katarina Babnik[2], Michael D. Burnard[3]

[1] University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies, Glagoljaška 8, Koper SI-6000, Slovenia; marko.posavcevic@famnit.upr.si.

[2] University of Primorska, Faculty of Health Sciences, Polje 42, Izola SI-6310, Slovenia; katarina.babnik@fvz.upr.si.

[3] University of Primorska, Andrej Marušič Institute, Muzejski trg 2, Koper SI-6000, Slovenia; michael.burnard@iam.upr.si.

Keywords: restorative environmental design, structural equation modelling, built environment, office

Introduction

Recent decades have marked a shift of focus towards a sustainable economy, and renewable energy and material use. With it came a new trend in building construction and design – namely, sustainable design. Sustainable design aims to decrease the negative effects the modern built environment has on nature: energy, water and material consumption, as well as waste production. This type of building design goes hand in hand with creating a built indoor environment that reduces negative health outcomes for people using it. Kellert (2005) argued that merely mitigating the adverse impacts on health isn't enough, driving the next change in building design paradigms towards restorative environmental design, and more recently, restorative environmental and ergonomic design (RED and REED, respectively). These amalgamate the ideas of environmentally sustainable design with the inclusion of nature into the built environment as a means to cater to the human affiliation to other life and life-like processes and thus promote health and well-being (Browning & Clancy 2014, Hartig 2004, Kaplan & Kaplan 1989, Kellert 2005). Therefore, our goal was to explore psychological mechanisms which drive these well-being and health promoting effects of nature in the built environment. A web survey was performed to (1) determine how the design of office spaces is linked to employee well-being and (2) assess the state of office spaces in Slovenia with regard to their adherence to the principles of REED.

Methods

Following a review of literature covering the introduction of bio-based materials and elements that reflect nature into the built indoor environment, key findings were itemized to form a questionnaire that was used in the study. Attention was given to the inclusion of wood as a natural element in office design. Participants were asked to rate the presence of visible wooden surfaces in their offices, as well as the haptic pleasantness of these surfaces. To measure restorativeness, the modified Perceived Restorativeness Scale (PRS; Pasini, et al. 2014) was included. 401 responses from office workers employed in various businesses in Slovenia were analysed using structural equation modelling.

Results

Our model revealed a relationship between various aspects of the presence of nature in office space and employee well-being. The model fit was assessed using multiple indices and compared with recommended values (Dion 2008). The presence of elements of nature (which includes the aspect of wood use in office design), perceived naturalness of the office space, and its restorativeness were linked to occupant well-being as shown in Fig. 1.

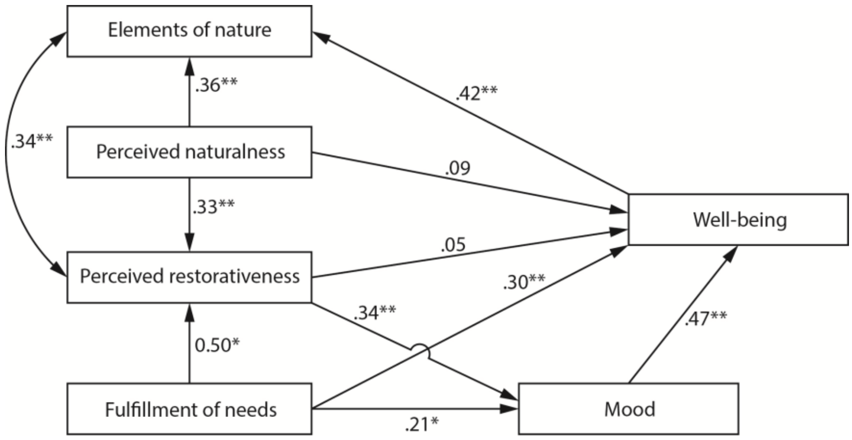


Figure 1: The fitted model of latent variable interrelationships (** significant at .001 level, * significant at .05 level).

Conclusions

Despite the modest strength of the relationships within the model, these results serve as an indicator to encourage designers, as well as builders and developers, to pursue design choices that impact occupant health. Implementing the REED paradigm and following evidence-based design protocols can provide positive human health impacts through building design.

References:

Browning W.D., Ryan C.O., Clancy J.O. 2014. 14 patterns of biophilic design. New York: Terrapin Bright Green, LLC.

Kaplan S., and Kaplan R. 1989. The experience of nature: A psychological perspective. New York: Cambridge University Press.

Kellert S. R. 2005. Building for life. Designing and understanding the human-nature connection. Washington: Island Press.

Pasini M., Berto R., Brondino M., Hall R., & Ortner C. 2014. How to measure the restorative quality of environments: The PRS-11. Procedia – Social and Behavioral Sciences, 159: 293-297.

Combining the science and design of plant cells and structures

Morwenna Spear[1], Yan Xing[2], Maurice Bosch[3], Simon Curling[1], Graham Ormondroyd[1]

[1] The BioComposites Centre, Bangor University, Deiniol Road, Bangor, LL57 2UW, U.K. m.j.spear@bangor.ac.uk

[2] Cardiff School of Architecture, Bute Building, King Edward VII Avenue, Cardiff, CF10 3NB, U.K.

[3] IBERS, Aberystwyth University, Penglais, Aberystwyth, SY23 3DA, U.K.

Keywords: bioinspired design, cell wall, turgor pressure, architecture, built walls

Timber and structures share a long connection (with the use of wood facilitating man's development throughout civilisation), and modern timber structures have advanced considerably during the 20th Century, leading to elegant designs for public arenas, sports stadia, concert halls, as well as increasingly tall multi-occupant dwellings. Many materials scientists, architects and designers believe that the wood cell wall may provide more than building material, instead providing the inspiration for biomimetics and bioinspired design.

This presentation will showcase examples of the role of plant tissues, and the plant cell wall in biomimetics. This will extend from the simple models of fibre composites, through design of novel buildings mimicking turgor pressure to achieve pneumatic or hydraulic structures, and the further application of non-structural roles of the plant cell wall in providing building services (communication, selective permeability and passive control of the interior environment). Examples of design and architecture which demonstrate this parity will be given, based on recent work by the Plants and Architecture cluster of the NRN-LCEE in Wales.

Development of the staining on the conifer wood in laboratory and outdoor conditions

Miha Humar[1*], Boštjan Lesar[2], Nejc Thaler[3], Davor Kržišnik[4]

[1] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia, miha.humar@bf.uni-lj.si

[2] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia, bostjan.lesar@bf.uni-lj.si

[3] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia, nejc.thaler@bf.uni-lj.si

[4] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia, davor.krzisnik@bf.uni-lj.si

Keywords: Scots pine, European larch, Norway spruce, staining fungi, climate

Aesthetic service life of the wood in the outdoor applications is predominately affected by weathering, and parallel development of the (blue) staining fungi. These disfigurements are one of the key reasons for the customers complains. Blue staining does not affect the mechanical properties of wood, however they contributes to the negative image of wood.

Al wood species does not have the same susceptibility to staining. It is well known, that scots pine sapwood is one of the most susceptible wood, on the other hand certain heartwood species perform considerably better. The objective of the present study was to compare the susceptibility of the key Central European softwood species, that are used for the building applications, namely: Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) sapwood and heartwood and European larch (*Larix decidua*). There were two sets of the experiments performed, laboratory and field trial (Figure 1). During the outdoor exposure samples were exposed based on the modified EN 927-3:2012 procedure. In contrast to the recommendation, samples were not facing south but north, to accelerate blue staining. The dimension of the samples was: 375 × 100 × 20 mm^3. In order to determine material climate, Scanntronik moisture content (resistance based sensors attached to Gigamodule) and temperature sensors were attached to the outdoor samples. All data was collected twice per day with Thermofox data loggers. The colour of the specimens and presence of the disfigurement was determined in predetermined intervals that were more frequent at the beginning and less frequent after first months. Samples were scanned periodically as well. In parallel laboratory experiments, samples (100 × 50 × 8 mm^3) were exposed in the chambers with various climate ranging from 66% to 98% at two different temperatures 20°C and 25°C. Presence of fungal disfigurements was determined once per week in the following 10 week.

Table 1: Development of staining on the surface of the respective wood species exposed in two different relative humidities. Marks indicates 0 = no blue stains; 1 = weakly blue stained; 2 = slightly blue stained; 3 = severely blue stained.

		Exposure (weeks)									
RH (%)	Wood	1	2	3	4	5	6	7	8	9	10
98	*L. decidua*	0,2	0,5	1,3	1,3	1,5	1,7	1,8	1,9	2	1,9
	P. abies	1,1	1,6	2,3	3	3	3	3	3	3	3
	P. sylvestris sap	1,2	1,8	2	3	3	3	3	3	3	3
	P. sylvestris heart	0	0,3	1	1,3	1,2	1,2	1,5	1,5	1,7	1,7
87	*L. decidua*	0,6	1,1	1,5	1,9	2,2	2,3	2,4	2,6	2,8	2,8
	P. abies	0	0,4	0,5	1	1	1	1	1	1	1
	P. sylvestris sap	0,1	0,3	0,6	1,1	1	1	1	1	1,1	1,1
	P. sylvestris heart	0	0,4	0,9	1,1	0,9	0,9	1	1	1	1

Table 2: Development of the blue staining on the specimens exposed in outdoor conditions (Figure 1) for 14 weeks between 6. 9. 2016 and 13.12.2016. Marks indicates 0 = no blue stains; 1 = weakly blue stained; 2 = slightly blue stained; 3 = severely blue stained.

Wood species	Weeks of exposure										
	1	2	3	4	5	6	7	8	9	10	14
L. decidua	0,0	0,0	0,7	1,0	1,0	1,0	2,9	3,0	3,0	3,0	3,0
P. abies	0,0	1,0	1,0	1,0	1,0	1,5	3,0	3,0	3,0	3,0	3,0
P. sylvestris sap	0,3	0,8	2,5	2,5	2,5	2,6	3,0	3,0	3,0	3,0	3,0
P. sylvestris hart	0,0	0,1	1,0	1,0	1,0	1,0	2,1	3,0	3,0	3,0	3,0

Figure1: Exposure of the samples to natural weathering on the field test site in Ljubljana

Table 3: Summary of the moisture measurements on the wood exposed to the natural weathering in the period between 6.9.2016 and 9.11.2016

	L. decidua	*P. abies*	*P. sylvestris sap*	*P. sylvestris h*
no. of meas.	124	124	124	124
MIN	12,3%	13,6%	13,2%	8,7%
MAX	34,8%	23,1%	64,3%	34,5%
Average	19,1%	17,2%	39,2%	14,8%
Median	18,2%	17,2%	44,4%	14,1%

Acknowledgments:

The authors acknowledge support Slovenian Research Agency within the framework of project L4-5517 and L4-7547, programme P4-0015 and infrastructure centre 0481-09.

Aesthetic of composites with the surface decorative veneers made of silver maple (Acer saccharinum L.)

Roman Réh

Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovak Republic
roman.reh@tuzvo.sk

Key words: decorative veneers, biobased composites, veneer properties, silver maple, veneering

One of the progressive forms of increasing the plantation production of trees suitable for their industrial processing is the establishment of intensive plantations (industrial plantations) in lowland and upland areas with fast-growing softwood and dense hardwoods species. They must be interesting for woodworking industry in terms of yield and quantity availability. Moreover, it could be wood species suitable for the production of decorative veneers, with positive aesthetics on the surface of composite materials, creating comfort from combining new design of biobased materials. Suitable species, according to the research carried out, is silver maple (*Acer saccharinum* L.).

Silver maple is an introduced species for Europe. This species grows under natural conditions in North America from New Brunswick, along Maine, southern Quebec, and southern Ontario to Michigan and Minnesota, south to southeastern South Dakota, eastern Nebraska, and eastern Oklahoma, and east to Mississippi and Georgia. It is also local in Louisiana and northwestern Florida (Harrar 1958). Silver maple is a member of the family *Aceraceae* (Coombes 1992).

Silver maple has white wide sapwood. The heartwood is pale pinkish, may be shaded of gray, green, or lavender. It is one of the fastest growing hardwoods of the forests. Also called river maple, this name derives from the common occurrence of the species along the river systems. Silver maple shares many of its sites with red maple, but the two species are easily distinguished. Silver maple is typically a much larger tree. The leaves of silver maple are often larger and more deeply fissured between lobes than those of red maple. The sawmilling production of silver maple is usually sold as soft maple. It is light in color and weight. The wood can be used as pulp for making paper. Lumber from the trees is used in furniture, cabinets, flooring, musical instruments, crates and tool handles, because it is light and easily worked. Because of the silver maple's fast growth, it is being researched as a potential source of biofuels. Silver maple produces a sweet sap, but it is generally not used by commercial sugarmakers because its sugar content is lower than in other maple species. Production of decorative veneers and application and aesthetics of wood composites are not reported extensively for silver maple (Lutz, 1971, Barbu et al. 2014).

Materials and Methods

Raw material for this research has Slovak origin and it was taken from forests around the city of Palárikovo, region of Komárno. 12 veneer logs with a length of 140 cm and with a diameter of 33.5 – 38.0 cm were not conditioned. Veneers were manufactured from fresh logs by off-center cutting in the Development workshops and laboratories of the Technical University in Zvolen. By means of interrupted off-center cutting a new and interesting grains and textures of silver maple were obtained. Veneers with the thicknesses of 0.5, 0.6, 0.7, 0.8, and 0.9 mm were dried up to a moisture content of 12 $\pm$ 3 % by drying at a temperature 110 $\pm$ 5 °C.

Silver maple veneers were subjected to a number of technological test procedures:

- Specific Glue Penetration to the Veneered Area
- Veneer Adhesion to the Particleboard Substrate

- Technological Properties of Veneers from the Aspect of Surface Finish
    a. Determination the local thickness of the paint
    b. Determination of the paint adhesion by means of the screen method (cross hatch)
    c. Determination of paint hardness by means of the pencil method
    d. Determination of the resistance to hot steam
    e. Determination of the resistance to a burning cigarette (burn resistance)
    f. Determination of the resistance to chemicals and selected consume liquids (spot resistance**)**

Transparent coatings were used only. There exist two reasons for the use of final coating material; aesthetics and protection from the end use environment. The esthetics of the final product varies in many ways, depending upon the selection of the various topcoats available and upon how the final topcoat is handled. The ultimate protection for any wood product finish is dependent upon proper selection of the topcoat for a specific end use.

Three types of clean topcoats were used:

a) Nitrocellulose Lacquer C 1008
b) Synthetic Acid Hardening Lacquer S 1711
c) Nitrocellulose Lacquer Basic C 1026 + Synthetic Acid Hardening Lacquer S 1711

Results and Discussion

The test results on glue penetration to the veneered area revealed no substantial glue penetration within the spread range 140 – 170 $g.m^{-2}$, inclusive of followed thicknesses.

It can be said from the results of tests performed that silver maple as an interesting species for application and aesthetics of wood composites and it is fully recommended. The quality of veneers made of silver maple does not differ from the quality of commonly used veneers and thickness 0.6 – 0.7 mm can be recommended for processing. All finished types of paints provide acceptable adhesion degree independently of the type of paint used pointing to excellent or very good properties of silver maple veneers with regard to the paint adhesion. Glue spread 140 – 150 $g.m^{-2}$ was proposed for particleboard.

REFERENCES

Barbu M.C., Irle M., Reh R. (2014): Wood Based Composites, Chapter 1 in Aguilera A., Davim P., Research Developments in Wood Engineering and Technology. IGI Global. Engineering Science Reference. Hershey, PA, USA, pp.1-45.

Harrar, E. S. (1958): Houghs Encyclopaedia of American Woods. Volume II. Robert Speller & Sons Publishers, New York, pp. 166-173.

Coombes A.J. (1992): Trees. Dorling Kindersley Limited. London, p. 199.

Lutz J.F. (1971): Wood and Log Characteristics Affecting Veneer Production. Forest Service research paper, Forest Products Laboratory, Madison, WI, 1971, pp. 1-35. http://www.fpl.fs.fed.us/documnts /fplrp/fplrp150.pdf.

Acknowledgements

The research described in the paper presented was supported by the Slovak Research and Development Agency under the contract No. APVV-14-0506 and APVV-0200-12. The author would like to thank the agency for the support of this research.

The Internal Structure of Modern Wood and Plastic Fibre Insulation Materials

Mark Irle[1], Pierre Vignon[2], Huyen Tran[3], Christine Delisée[3]

[1] Ecole Supérieure du Bois, LIMBHA, 44000 Nantes, France, mark.irle@ecoledubois.fr

[2] FINSA France, 40110 Morcenx, France.

[3] I2M, UMR 5295, CNRS, University of Bordeaux, Talence, France

Keywords: wood, fibre, polyester, insulation, structure

Introduction

Thick wood fibre-based insulation products intended for enhancing the thermal performance of buildings have been made by companies like STEICO (www.steico.com) for many years. Their products compete with glass-wool, rock wool and expanded polystyrene. The wood-based products have the advantages of being largely made from a renewable material and have a low embodied energy content. On the other hand, their thermal performance in terms of conductivity, at 0.038 W/m.K, is slightly below that of non-renewable products, e.g. glass wool has a conductivity of 0.035 W/m.K. In addition, wood fibre products tend to become compressed during storage and transport and the thickness does not always recover and this affects thermal performance. The main drawback of wood-based insulation materials is their price; they are more expensive and consequently, they tend to have about 2% of the market.

The Ecole Supérieure du Bois (ESB) is part of a consortium headed by the University of Bordeaux that is trying to help two companies, STEICO and FINSA, improve or develop new wood-based insulation products. One of the main contributions that ESB is making to the project is a characterisation of existing and new fibre-based products using its environmental scanning electron microscope (ESEM). This short paper presents some images that show how the plastic component of these fibreboards binds the much shorter wood fibres into a cohesive product.

Materials and Methods

Wood fibres were made by the FCBA, Grenoble, from and loblolly pine (*Pinus teada*), Maritime pine (*Pinus pinaster*), poplar (*Populus spp*), and a *Eucalyptus spp.* These species were refined at different energies ranging from 36 to 215 kWh/t, thus producing very coarse fibre through to very fine. The fibres were dried and stored in laboratory conditions before being mixed with a two-component polyester fibre using a pilot-scale insulation panel manufacturing line.

Samples of approximately 1 cm^3 were cut from the panels and then teased apart to reveal the interior structure in the X-Y plane. These specimens were examined using an Environmental Scanning Electron Microscope (Quanta 250 made by FEI).

Results

The polyester fibre has two components: a strong central fibre and an outer coating of a lower molecular weight polyester that melts, or at least softens, between 120-140 °C depending on the fibre type. It is this outer coating which acts as an adhesive that binds the wood fibres into an insulation panel. The polyester fibres are easily identified in Figure 1 because they are longer, thinner and more consistent than the wood fibres. It can be seen that the plastic fibres have a constant diameter unless they make contact with another plastic or a wooden fibre. In which case surface tension effects cause the outer coating to deform and fuse to form a joint.

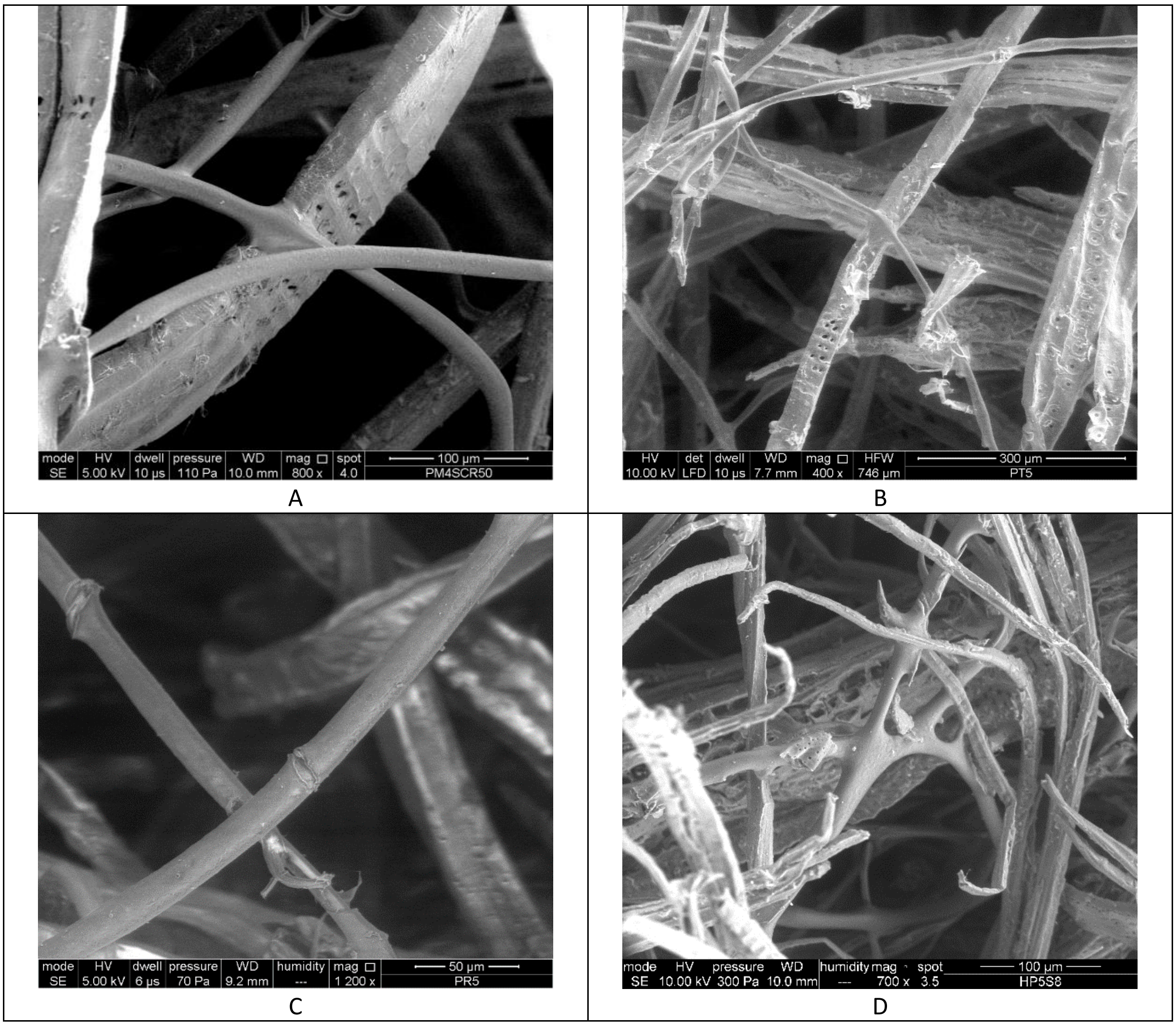


Figure 1. (A) Maritime pine, (B) Loblolly pine, (C) Poplar and (D) Eucalyptus.

Acknowledgments

This research is sponsored by the French Environment and Energy Management Agency under grant number ADEME BIP2013-ECOMATFIB. The authors also thank the French National Agency for Research for supporting this study through XYLOFOREST (ANR-10-EQPX-16).

Potential use of plant extracts for protection of wood veneers

René Herrera[1], Daniela Thomas da Silva[2], Jalel labidi[3]

[1] Biorefinery processes group, Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa 1, 20018, San Sebastian, Spain. renealexander.herrera@ehu.eus

[2] Centre of Rural Sciences, Federal University of Santa Maria, Ave. Roraima 1000, 97105-900, Santa Maria, Brazil. dthomasdasilva@gmail.com

[3] Biorefinery processes group, Chemical and Environmental Engineering Department, University of the Basque Country, Plaza Europa 1, 20018, San Sebastian, Spain. jalel.labidi@ehu.eus

Keywords: wood-preserving products, decay resistance, *Ocotea lancifolia*

In the approach of multiple-use from natural forests, the present study aims to obtain, characterize and find applications to leaf crude extracts from the native Brazilian tree *Ocotea lancifolia* in order to use as wood-preserving bio-agent. Firstly, the obtained leaf extracts were partitioned with ethyl acetate and butyl alcohol in order to obtain two phenolic-rich fractions. Subsequently the physicochemical properties of the crude extract and fractions were evaluated by Fourier transform infrared and thermo-gravimetric analysis to confirm the differences on structure, stability and purity of the evaluated products. Afterwards, the phenolic, flavonoids and tannins contents as well as the antioxidant capacity were measured to know the feasibility of implementing these products as wood preservatives. Finally, wood veneer samples from downy birch (*Betula pubescens* L.) and beech (*Fagus sylvatica* L.) were impregnated with the crude extract and its fractions (at 1 and 4%), and evaluated with respect to their appearance, product retention and the resistance against two wood-destroying fungi. The results showed lower potential of the crude extract compared with its fractions regarding the total phenolic content, antioxidant activity and purity of polyphenolic compounds. Moreover, the retention of products in wood veneers presented similar profiles with high retention when applying at [4%] and not affected by the solvent nor veneer variety (figure 1), however the use of additives would improve the retention. The decay resistance (Table 1) test showed that the crude extract and ethyl acetate fraction at [4%] were the most effective treatments to reduce the action of two wood-rot fungi (mass loss < 8%). In conclusion, the refined fractions presented superior thermal stability, higher phenolic content and antioxidant activity than crude extract. However, despite impurities the crude extract reduced the fungal attack on veneer samples, providing a renewable source of natural wood preservatives.

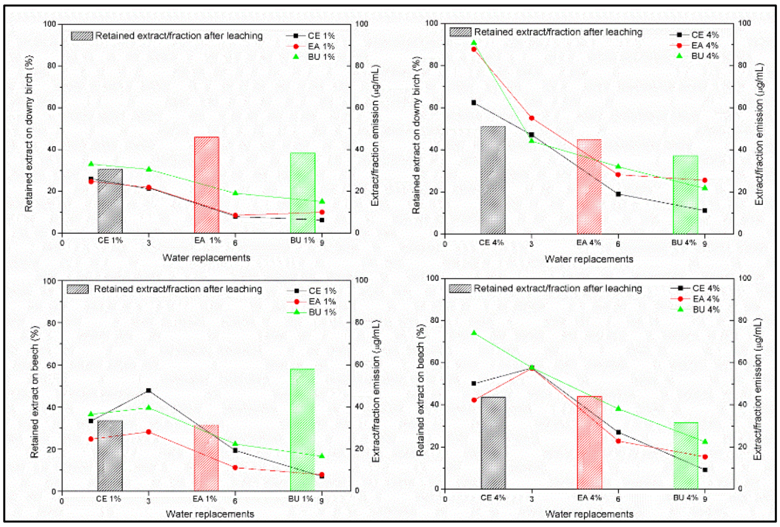


Figure 1: Measurement after leaching cycles and UV evaluation of extract/fraction emission.

Table 1 - Average mass loss (%) of veneers treated with different concentrations of extract and fractions.

No.	Treatment	Mass loss [%]			
		G. trabeum		***T. versicolor***	
1	CE 1%	15.5 ± 5.1	*ab*	57.7 ± 24.1	*b*
2	CE 4%	6.6 ± 2. 7	*a*	3.1 ± 0.6	*a*
3	EA 1%	17.5 ± 3.7	*b*	1.8 ± 0.4	*a*
4	EA 4%	7.2 ± 5.2	*a*	2.3 ± 0.7	*a*
5	BU 1%	18.5 ± 5.8	*b*	68.7 ± 8.0	*b*
6	BU 4%	22.9 ± 3.8	*b*	55.4 ± 10.5	*b*
	Control samples	48.2 ± 9.3	*c*	48.1 ± 6.6	*b*

Data are reported as mean ± standard deviation. Different letters within the columns refer to means statistically different by Tukey test ($P < 0.05$). CE: Crude extract; EA: Ethyl acetate fraction; BU; Butanolic fraction.

References

Metrouh-Amir, H., Duarte, C.M.M., Maiza, F., 2015. Solvent effect on total phenolic contents, antioxidant, and antibacterial activities of Matricaria pubescens. Industrial Crops and Products 67, 249-256.

Sen, S., Tascioglu, C., Tırak, K., 2009. Fixation, leachability, and decay resistance of wood treated with some commercial extracts and wood preservative salts. International Biodeterioration & Biodegradation 63, 135-141.

Tascioglu, C., Yalcin, M., Sen, S., Akcay, C., 2013. Antifungal properties of some plant extracts used as wood preservatives. International Biodeterioration & Biodegradation 85, 23-28.

Acknowledgments:

Authors would like to the Basque Government for the scholarship of young researchers training granted to R. Herrera.

Evidence of low impact of hemp bio-aggregates on the thermal conductivity of hemp concrete

César Niyigena[1], Sofiane Amziane[1], Alaa Chateauneuf[1]

[1]Université d'Auvergne, Institut Pascal, Polytech' Clermont-Ferrand – 63174 Aubière Cédex, France

cesar.niyigena@uca.fr, sofiane.amziane@uca.fr, alaa.chateauneuf@uca.fr

Keywords: hemp bio-aggregates, hemp concrete, thermal conductivity, low impact, variability.

The impact of Hemp Bio-Aggregates (HBA) on Hemp Concrete (HC) have been treated in previous studies (Arnaud and Gourlay 2012, Stevulova et al. 2013). In those studies, used HBA are of limited varibility. Morever, the considered properties are mainly based on particle size and HBA origin. Since many parameters (curing conditions, the specimen size, etc.) are taken into account at the same time, it comes difficult to assess the impact of HBA due to parameter interferences.

The present study focuses on the thermal conductivity variability of HC due to HBA. The selection procedure for nine HBA has been developed in a previous study (Niyigena et al., 2015) in which different characteristics are taken into account. The aim was to predict the impact of HBA on HC performance. The study revealed three categories of HBA, which are supposed to result in three mechanical performance (high, medium and low) of HC. Thus, it is recommended to conduct tests in order to validate the predicted results. At one hand, results on mechanical performance are consistent with the prediction (Niyigena et al., 2017). At the other hand, result for thermal conductivity are not very impacted by HBA type, they are presented in the herein study.

The thermal conductivity was measured by the "hot wire" method illustrated in (Fig. 1). Specimens used are the same as for mechanical test (Niyigena et al., 2017). Thus, for a given measurement, two specimen are used (Fig.1), and an average value is considered, (Table 1).

(a) cylinders (b) cubes (c) hot wire with contact surfuses

Figure 2: Experimental devices for thermal conductivity test.

Table 1: thermal conductivity [W/m.K] per HBA, specimen type and direction of heat flux at different ages.

	Specimen type	**cylinder (11x22cm^2)**				**cube (15x15x15cm^3)**			
	Age of test (days)	**30**	**60**	**90**	**180**	**30**		**180**	
	Direction					⊥	**//**	⊥	**//**
Hemp bio-aggregates type	**C2**	0.116	0.107	0.089	0.083	0.118	0.113	0.100	0.095
	C4	0.094	0.091	0.075	0.075	0.100	0.092	0.084	0.083
	C5	0.124	0.110	0.089	0.087	0.124	0.111	0.103	0.094
	C12	0.093	0.093	0.083	0.080	0.111	0.101	0.098	0.092
	C3	0.111			0.092				
	C6	0.119			0.091				
	C10	0.101			0.087				
	C11	0.101			0.079				
	C13	0.096			0.075				

The thermal conductivity varies according to HBA type, at 30 days a minimum of 0.093 W / m.K and a maximum of 0.124 W / m.K are observed for hemps C12 and C5, respectively. However, it is to note that at 180 days the thermal conductivity decreases below 0.1 w / m.K. In fact, the more the material dries, the more the water contained in the pores evaporates; these pores are then empty or filled with air, which increases the insulating power of the material. At this age, a minimum of 0.075 W / m.K and a maximum of 0.092 W / m.K are observed for HBA C4, C13 and C3, respectively. Moreover, the thermal conductivity may also vary according to the orientation of HBA or the direction of heat flow with respect to the compaction energy, and also the shape of the specimen used. In this latter case, the issue is about the boundary/side effect.

Results show that the thermal conductivity is higher in the direction of heat flow perpendicular to the direction of compaction with values ranging from 0.084 to 0.124 W / m.K whatever the type of HBA type and age. In the parallel direction, the results vary from 0.083 to 0.113 W / m.K. For specimen type, the tests are carried out with the heat flux parallel to the direction of compaction, which leads to low thermal conductivity for cylinders. This is due to its rounded shape and small contact area (Fig. 1 (c)), heat loss is likely to occur, leading to low thermal conductivity.

Results for different HBA show low variability; however, the performed analyses show that the specimen type and direction of heat flux are likely to contribute to observed variability. Hence, further investigations taking into account the specimen type and the protocol may allow to better understand this variability and help to fix the standards to be used for the characterization of HC.

References

Arnaud L. and Gourlay E., "Experimental study of parameters influencing mechanical properties of hemp concretes," Construction and Building Material, vol. 28, no. 1, pp. 50–56, 2012.

Stevulova N., Kidalova L., Cigasova J., Junak J., Sicakova A., and Terpakova E., "Lightweight composites containing hemp hurds," Procedia Eng., vol. 65, pp. 69–74, 2013.

Niyigena C., Amziane S., and Chateauneuf A. "Etude de la variabilité des caractéristiques de granulats de chanvre," in Rencontres Universitaires de Génie Civil, 2015.

Niyigena C., Amziane S., and Chateauneuf A. Investigating Hemp Concrete Mechanical Properties Variability Due to Hemp Particles. In: Mechanics of Composite and Multi-functional Materials, Volume 7. Springer International Publishing, 2017. p. 9-17.

Water vapour sorption characteristics of thermally modified Norway spruce particles

Susanna Källbom[1], Michael Altgen[2], Kristoffer Segerholm[3], Dennis Jones[4], Holger Militz[5], Magnus Wålinder[6]

[1] KTH Royal Institute of Technology, Building Materials, SE-100 44 Stockholm, Sweden, susanna.kallbom@byv.kth.se

[2] Georg-August University Göttingen, Burckhard-Institute, Wood Biology and Wood Products, Büsgenweg 4, DE-37077 Göttingen, maltgen@gwdg.de

[3] SP Technical Research Institute of Sweden, Sustainable Built Environment, SE-114 86 Stockholm, Sweden

[4] DJ Timber Consultancy Ltd, Neath, United Kingdom, dr_dennisjones@hotmail.co.uk

[5] Georg-August University Göttingen, Burckhard-Institute, Wood Biology and Wood Products, Büsgenweg 4, DE-37077 Göttingen, hmilitz@gwdg.de

[6] KTH Royal Institute of Technology, Building Materials, SE-100 44 Stockholm, Sweden, magnus.walinder@byv.kth.se

Keywords: Wood modification, Norway spruce, water vapour sorption

There is an increased interest in adding value to wood processing residuals and also of using modified wood. Thermal modification is one type of wood modification used to alter the sorption properties of wood, which can imply advantages in the use of new bio-based building material products. The objective of this study was to modify wood particles by thermal modification and evaluate the water vapour sorption properties. The thermal modification was performed on circle sawed Norway spruce wood particles. The equipment used for the thermal modification was a steam-pressurised laboratory-scale treatment reactor (Altgen *et al.* 2016). The treatment process parameters involved the temperature (T), pressure (p) and relative humidity (RH). The pressure was regulated using a heated external water reservoir. Two different thermal modification processes were executed TM1 (T=150 ˚C, RH=100%) and TM2 (T=180 ˚C, RH=40%), both at the constant maximum pressure of 0.47 mPa. The water vapour sorption characteristics were measured using dynamic vapour sorption (DVS). The tests were carried out for unmodified (UM) and thermally modified (TM1 and TM2) samples in three cycles for each ranging from 0-95% RH, at 25 ˚C. The results from the DVS analysis showed a clear difference in equilibrium moisture content (EMC) between the unmodified and thermally modified samples, which was expected. There was also a difference between the TM1 and TM2, indicating a lower adsorption curve for the first cycle of the wood particles modified at the higher temperature and lower RH (TM2, T=180 ˚C, RH=40%). The results are in agreement with other studies on the effect of humidity during heating of thermally modified wood (Endo *et al*. 2016 and Altgen *et al.* 2016). The difference between the first and subsequent sorption cycles is suggested to be related to softening caused by the increase in RH during the process. Results from the 1st and 2nd cycles of UM and TM1 are shown in Fig. 1.

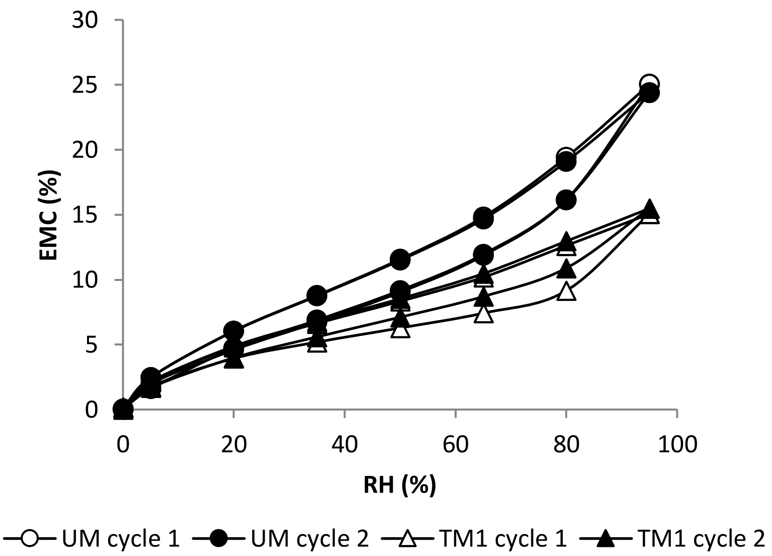


Figure 1: Water vapour sorption isotherms of unmodified, UM and thermally modified, TM1 (T=150 ˚C, RH=100%) spruce particles in two cycles

References

Altgen, M., Willems, W. and Militz, H. 2016. Wood degradation affected by process conditions during thermal modification of European beech in a high-pressure reactor system. European Journal of Wood and Wood Products, 74, 5: 653-662

Endo, K., Obataya, E., Zeniya, N. and Matsuo, M. (2016). Effect of heating humidity on the physical properties of hydrothermally treated spruce wood. Wood Science and Technology, 1-19 (In press). DOI 10.1007/s00226-016-0822-4

Acknowledgments:

Many thanks to all the people involved at Department of Wood Biology and Wood Products at Georg-August-Universität Göttingen. The COST Action FP1303 “Performance of Bio-based building Materials” is greatly acknowledged for making this Short-Term Scientific Mission possible.

The Curing Behaviour of Urea-Formaldehyde Adhesive in the Presence of Chemically Treated Narrow-Leaved Ash (*Fraxinus angustifolia* Vahl. ssp. *Pannonica* Soo & Simon)

Mlađan Popović[1], Nevena Vukić[2], Jasmina Popović[1], Milanka Điporović-Momčilović[1], Jaroslava Budinski-Simendić[2], Ivana Gavrilović-Grmuša[1], Ivan Ristić[2]

[1] Kneza Višeslava 1, Belgrade, Serbia, University of Belgrade - Faculty of Forestry, mladjan.popovic@sfb.bg.ac.rs

[2] Bulevar cara Lazara 1, Novi Sad, Serbia, University of Novi Sad - Faculty of Technology, nevena.vukic@gmail.com

Keywords: Narrow leaved ash, wood flour, chemical pretreatments, UF adhesive, curing reaction

The influence of the pre-treatments of Narrow leaved ash on the curing behaviour of urea-formaldehyde (UF) adhesive was studied in this work. Differential scanning calorimetry was used to monitor the reaction of UF adhesive mixed with the non-treated and treated wood flour. Three different pre-treatments were chosen, one with sodium carbonate solution (0.03 g/g of dry wood), one with acetic acid solution (0.06 g/g of dry wood) and one with distilled water. The treatments were performed in the autoclaves heated to 100 °C, during 1 h. Differential Scanning Calorimetry (DSC) was used to test the curing reaction in non-isothermal regime, in the temperature range from 30 °C to 180 °C, and with three different heating rates (5, 10 and 20 °C/min). Mixes of UF adhesive and the wood flour were prepared with the addition of 10 % of wood flour per dry adhesive. Before the DSC tests the hardener (ammonium sulphate) was added to each mix (1 % of dry hardener per dry adhesive), and the adhesive mix was diluted to 50 %. DSC scans were performed with approximately 5 mg of UF adhesive mix placed inside the aluminium pan and hermetically sealed.

The application of Friedman izoconversional model, on the whole range of the curing reactions of UF adhesive mixes, have showed a different curing behaviour between the test series (Fig. 1). The Friedman model does not introduce any mathematical approximations (Starink 2003, Yang *et al.* 2013), and being the differential method it is considered to be more suitable to analyse data obtained from DSC measurements (Vyazovkin *et al.* 2011). The applied Friedman model shows that the activation energies of all UF adhesive mixes are decreasing at the beginning of the reaction, having the values between the 87.1 - 89.7 kJ/mol at the 10 % of conversion, down to 74.7 - 77.1 kJ/mol at the 30 % of conversion.

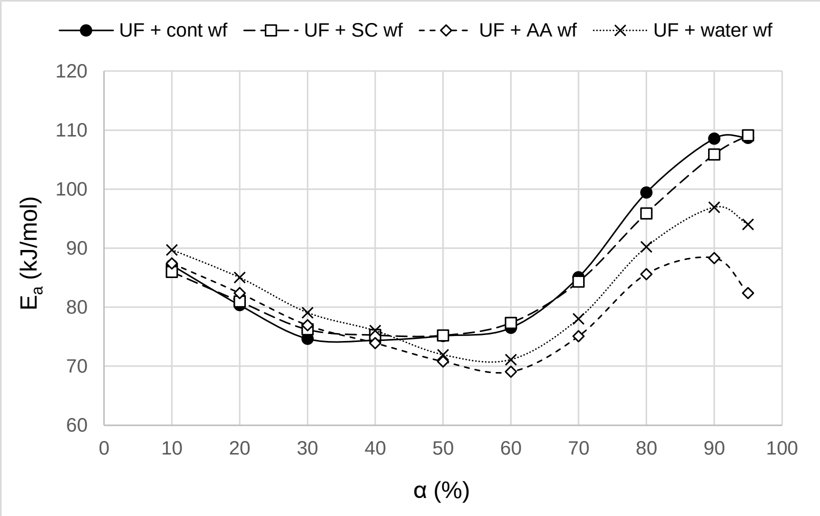


Figure 1: Dependance of the activation energy on the conversion degree of the curing reactions for the UF adhesive mixes obtained by Friedman method (SC - sodium carbonate, AA - acetic acid)

The range of conversion from 30 to 60 % shows further decrease of activation energy for the UF adhesive systems with wood flour from acetic acid and water treatments. From the point of 60 % of conversion, the activation energy of all UF adhesive mixes is constantly increasing until the 90 % of conversion, which may suggest that the reaction was controlled by diffusion rather than by kinetic factor (Gao *et al.* 2006). However, at that final stage of conversion, the influence of acetic acid treatment have resulted in the lowest levels of activation energy of the relevant UF adhesive mix, while the UF adhesive mixes with control (non-treated) wood flour and the wood flour from sodium carbonate treatment were showing the highest values of activation energies. Furthermore, the predictions of isothermal cure obtained from non-isothermal data have showed that the UF mixes with wood flour obtained from acetic acid and water treatments have achieved significantly shorter reaction times in comparison to other two UF adhesive systems.

References

Gao J., Zhao M., Qin J. 2006. Curing Kinetics of o-Cresol-formaldehyde Epoxy Resin/3-Methyl-tetrahydrophthalic Anhydride/Organic-Montmorillonite Nanocomposite by Isoconversional Methods, Iranian Polymer Journal, 15, 5: 425–432

Starink M. J. 2003. The determination of Activation Energy From Linear Heating Rate Experiments: a Comparison of the Accuracy of Isoconversion Methods. Thermochimica Acta, 404: 163–176

Vyazovkin S., Burnham A. K., Criado J. M., Pérez-Maqueda L. A., Popescu C., Sbirrazzuolie N. 2011. ICTAC Kinetics Committee Recommendations for Performing Kinetic Computations on Thermal Analysis Data. Thermochimica Acta, 520: 1–19

Yang G., Yuan Z., Yang Z., Zhang M. 2013. Nonisothermal Curing Kinetics of a Novel Polymer Containing Phenylsilylene and Propargyl–Hexafluorobisphenol A Units. Journal of Applied Polymer Science, 127: 3178–3185

Modifying wood with poly(butylene succinate). Influence of humidity on oligomers diffusion into the wood cell walls by screening of heat treatment parameters

Charlotte GROSSE[1,3], Marion NOËL[1], Lauri RAUTKARI[2], Philippe GERARDIN[3]

[1] Department Architecture, Wood and Civil Engineering, Berne University of Applied Sciences, Solothurnstrasse 102, Postfach 6096, CH-2500, Biel, Switzerland, charlotte.grosse@bfh.ch

[2] Department of Forest Product Technology, Aalto University, Tekniikantie 3, 16400, Espoo, Finland, lauri.rautkari@aalto.fi

[3] LERMaB, EA 4370, Université de Lorraine, Faculté des Sciences et Technologies, BP 70 239, F-54506 Vandoeuvre-lès-Nancy, France, philippe.gerardin@univ-lorraine.fr

Keywords: modified wood, bio-polymer, bulk impregnation, humidity

As renewable material, wood has many advantageous properties such as workability, mechanical strength, sustainability and pleasant aesthetic features. However, wood is sensitive to its environment, especially regarding moisture. Due to its chemical composition, dimensional stability against humidity and biological resistance of wood are limited. Chemical modification of wood with polybutylene succinate (PBS) has been reported to confer interesting properties to wood for outdoor applications (Noël *et al.* 2015a, 2015b, Vitkeviciute *et al.* 2014). This treatment was based on the hot impregnation (90°C) of PBS in oven-dried beech wood (*Fagus sylvatica L.*), followed by a curing step at 100/120°C for 6h/96h.

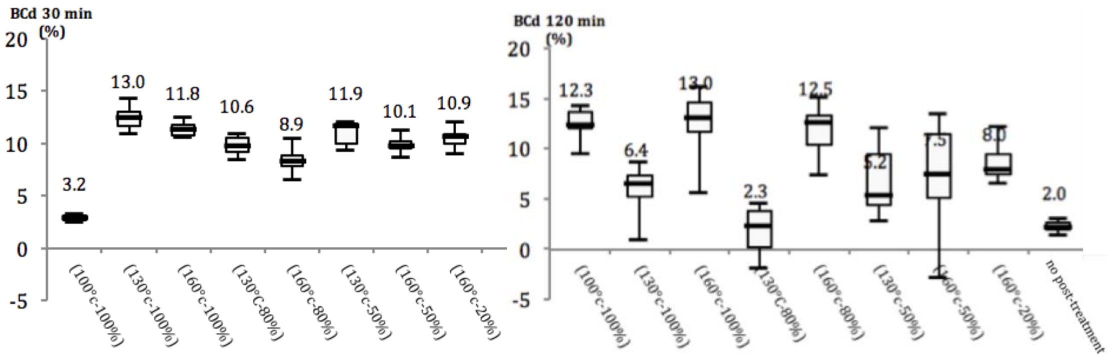
The dry treatment conditions did not allow any penetration of the oligomers in wood cell walls, thus any anti-swelling efficiency (ASE). The mechanical properties were not influenced either. However, the PBS lumen-filling led to a substantial decrease in wood hygroscopicity. Moreover, a good retention of oligomers into the wood lumens was observed, with ca. 80% retention rate of the impregnated polymers in wood during water leaching.

Humid treatment conditions were observed to allow a partial diffusion of the oligomers into the cell walls, most likely because of water acting as swelling agent inducing partial penetration of oligomers in the cell wall. Humid treatment conferred ASE of 60% to 70%.

This article reports the systematic characterization of wood impregnated with PBS and post-treated under varying conditions of temperature, relative humidity (RH) and duration. After post-treatment, samples are air-dried and oven-dried until constant weight. The influence of post-treatment conditions on PBS curing and diffusion into the cell walls was evaluated regarding dimensional and weight variations during treatment. Swelling after impregnation (Si) was always lower than 2%.

Impregnation yield (IY) was about 65% to 70% for all variants. The improvement of wood properties relies on the amount and persistence of PBS into the wood cell walls. BC_d (Fig.1) determination characterized PBS diffusion into the walls. At temperature higher than 100°C, BC_d is not significantly influenced by the process parameters of a short post-treatment (30 min). The long treatment (120 min) shows however differing BC_d according to the pair temperature/humidity.

Figure 1: Dry bulk coefficient (BC_d) of PBS impregnated wood after different post treatments



References

Noël M., Grigsby W., Vitkeviciute I., Volkmer T. 2015a. Modifying wood with bio-polyesters: analysis and performances. International Wood Products Journal, 6 (1), 2015:14-20

Noël M., Grigsby W., Volkmer T. 2015b. Evaluating the extent of bio-polyester polymerization in solid wood by thermogravimetric analysis. Journal of wood chemistry and technology, 35, 2015:325-336

Vitkeviciute I., Noël M., Volkmer T. 2014. Water vapor sorption behavior of wood modified with bio-(co)-polyesters. 3rd International Conference on Processing Technologies for the Forest and Bio-Based Products Industries (PTFBPI14), COST Action FP1006 session, Kuchl

Acknowledgements

The authors would like to thank the COST Action FP1303 for financing this research project (funded project no. C15.0090).

Decreasing the hygroscopicity of wood with nanoparticles

Miklós Bak[1], Ferenc Molnár[2]

[1,2] University of Sopron; Simonyi Károly Faculty of Engineering, Wood Sciences and Applied Arts; Hungary; [1] bak.miklos@nyme.hu; [2] ferimoln@gmail.hu

Keywords: hygroscopicity, nanoparticles, swelling

The improving effect of nanoparticles on wood properties is barely known nowadays. Contrarily, the nanoparticles are commonly used in other industries because of their favourable properties. For example, it is possible to improve the properties of polymers remarkably. The novelty of the research is the application of such new nanoparticles, which utilization in the wood industry was not investigated yet. The planned treatment will likely elongate the lifetime of the wood-based products.

With the use of the hydrophobous properties of the titanate nanotubes and nanowires (provided by Nanobakt Kft., Hungary) it is possible to create "hydrophobic wood". The changes in the environmental parameters, the temperature and the humidity will have less effect on the wood material treated with the above mentioned nanoparticles. As a result of that is less shrinking or swelling, and that leads finally to the increased dimensional stability. The improvement of wood materials' dimensional stability by nanoparticles has the favourable property contrary to earlier methods, that this modification does not decrease other physical properties of wood. For the reduction of the shrinking anisotropy, heat treatment methods are current, but they cause significant decrease in the strength and elasticity depending on the treatment parameters. Accordingly, such modified wood material is only suitable for cladding or decking, but not for load-bearing structures.

The expected result of the research is the improvement of the dimensional stability as a result of impregnation with nanoparticles. Because the wood-water relations are essential at all utilization fields, the expected positive results of the research can serve useful information regarding the expandability of the utilization fields of wood. It is possible to create such dimensionally stable wood material which do not have negative properties as the "price" for outstanding dimensional stability.

Overall, we can state according to our investigations so far, that the impregnation with nanoparticles was successful. Shrinking and swelling properties decreased remarkably in case of all the four investigated wood species (Fig. 1). The improvement of the swelling values shows some moderation compared to the improvement of the shrinking values, which is explained by the leaching of the nanoparticles. As a side effect of the treatments, a slight colour change could be observed as well. We are looking forward to the results of the other planned investigations, trusting in the further success of the research.

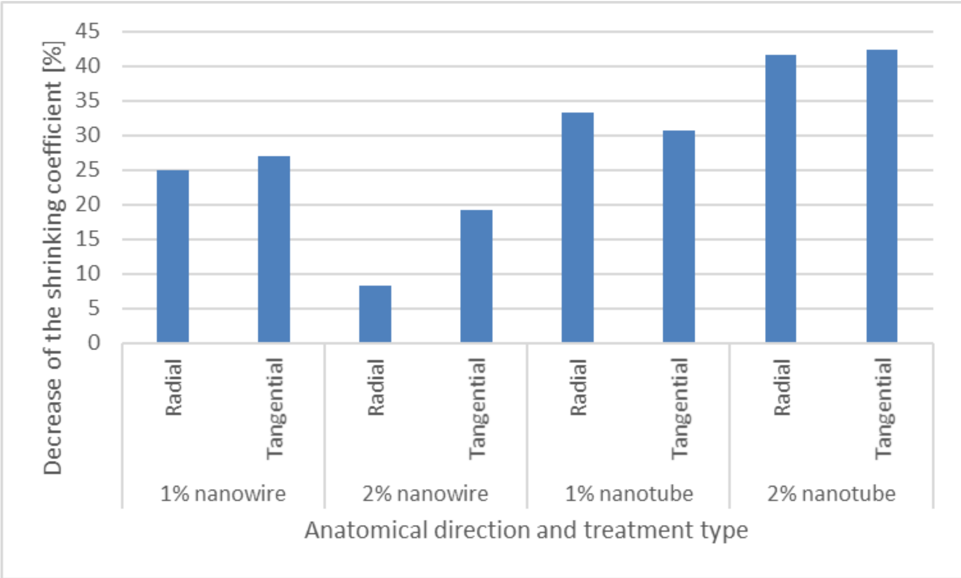


Figure 1: Decrease of the shrinking coefficient in case of poplar wood, as a result of different nanoparticle treatments

Acknowledgments: This research was supported by the National Research, Development and Innovation Office - NKFIH, in the framework of the project OTKA PD 116635 with the title "Improvement of the most important wood properties with nanoparticles".

Using reinforced GLT laths for constructing grid shells without supports

Tõnis Teppand[1]

[1] Kreutzwaldi 5, Tartu, 51014 Tartumaa, Estonia, Estonian University of Life Sciences, tonis.teppand@emu.ee

Keywords: grid shell, tenon, mortise, half joint, GLT

Shell structures are not very common until today because of complicated modelling, strength analysis and construction technology. It makes shells and grid shells in it too expensive compare with other types of buildings and technologies.

Grid shell technology needs normally big supporting system of construction jacks, beams and platform of plywood. The first two layers of laths connected to each other with finger joints and gluing as unlimited will mounted on the platform. After that the needed points will lowered until the projected level and shape. The edges will fixed to the exterior beams (Harris et al. 2004: 2).

The idea of constructing grid shells without supports came from technology of making baskets, not as usual from bottom to the edges but on the opposite. Fixing the laths to the external beam or foundation capable to carry cantilever loads the shell structure start "rising" towards the top. To fix the laths together and carry loads will be used half joints. It is no need to have unlimited laths any more. The longitudinal connections between the laths will done with tenon at one end and mortise at the other end (Figure 1).

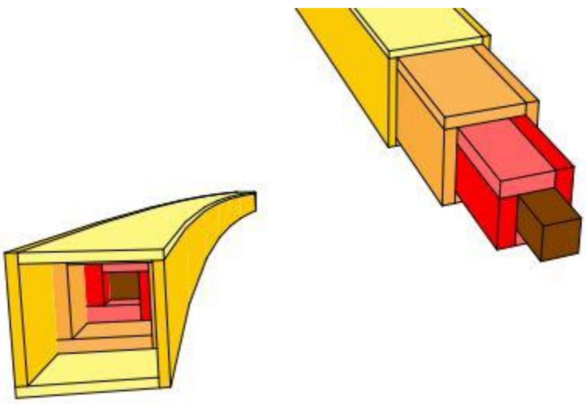


Figure 1: GLT laths with mortise and tenon for longitudinal connection (Author´s drawing)

The best and cheapest way to produce them is to glue the laths together of like hollow tube in tube of lamellas made of timber. The lamellas of different kind of timber with different physical properties can used.

Design of the shell shape will done as 3D model (software Rhinoceros for example). After that the laths will projected on the surface (Teder et al. 2015). The data of crossing points (x, y, z) is needed for CNC-workstations to produce the half joints on exact place.

During mounting the laths will be bended until the half joint locks. The bending and twisting forces inside the laths keep the designed shape of grid shell in correct form from the very beginning, because real shape of the laths will form as spline. After second row of 1st and 2nd layer will start mounting of 3rd and 4th layer of laths etc. The amount of layers depend on shape, carrying loads used materials of lamellas, glue type what will calculated with the software of finite element method.

References

Harris, R., Dickson, M., Kelly, O. (2004). The Use of Timber Gridshells for Long Span Structures. - 8th International Conference on Timber Engineering. Lahti, Finland.

Teder, T., Teppand, T., Sirk, M. 2015. Võrkkooriku mudeli katsetamine. (Katseraport). Eesti Maaülikooli metsandus- ja maaehitusinstituut. Tartu

Analysis of HWP production and impact on carbon storage in Lithuania

Marius Aleinikovas[1], Mindaugas Škėma[2], Lina Beniušienė[3]

[1] Liepu 1, Girionys, Kaunas distr., Lithuania, Institute of Forestry, LAMMC, marius.aleinikovas@mi.lt

[2] Liepu 1, Girionys, Kaunas distr., Lithuania, Institute of Forestry, LAMMC, mindaugas.skema@mi.lt

[3] Liepu 1, Girionys, Kaunas distr., Lithuania, Institute of Forestry,LAMMC, lina.beniusiene@mi.lt

Keywords: harvested wood products, climate change, carbon stock.

Carbon storage in harvested wood products (HWP) is an internationally recognised measure to mitigate climate change. The Intergovernmental Panel on Climate Change (IPCC) provides reporting guidelines on how to estimate carbon stocks and their changes in harvested wood products (HWP) (IPCC, 2006; IPCC, 2014). However, after forest harvesting a significant amount of carbon is removed and might be stored in HWP, including building materials, furniture, paper, etc. Method requires estimating the HWP carbon pool and its changes for the three default HWP categories, namely: sawn wood, wood-based panels, paper and paperboard.

Historical data for different time series on production and trade of HWP were obtained from three sources: FAO statistics (1992-2015), national statistics office (1940-1991) and literature (1960-1991). (fig 1):

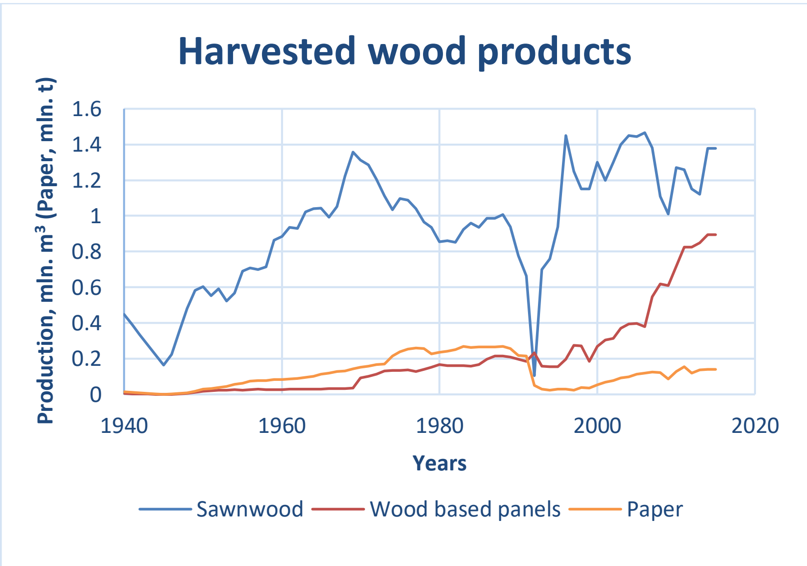


Fig. 1. Historical HWP changes. These estimates are based on data obtained from national statistics (1940-1991) and FAO data (1992-2015).

Lithuania is a net exporting country of industrial roundwood. In in the last years (2010-2014), the export of industrial roundwood accounted to almost 1.7 million m^3 on average. This corresponds to 33% of domestic production of industrial roundwood (LSY, 2015). It is evident that huge amount of domestic carbon is exported together with industrial roundwood

We estimated carbon storage in HWP by applying different methods and compared the results. The presented estimates are in line with internationally agreed (UNFCCC) carbon accounting principles.

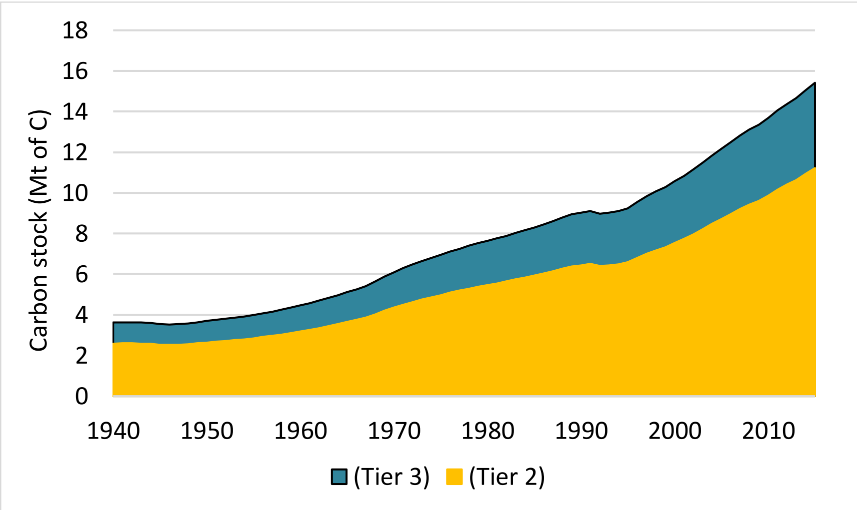


Fig. 2. Total carbon stocks in HWP under the IPCC Tier 2 and Tier 3 methods. These estimates are based on data obtained from national statistics (1940-1991) and FAO data (1992-2015).

The highest carbon stock (15,4 Mt) at the end of the study period (year 2015) was observed when the Tier 3 method was applied. The carbon inflow into the pool of HWP in all cases was estimated to be 40% higher when applying the material flow analysis compared to the IPCC default (Tier 2) method.

References

IPCC 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: Eggleston H. S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Japan: Institute for Global Environmental Strategies (IGES).

IPCC 2014 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. In: Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Switzerland: IPCC.

LSY (2015) Lithuanian Statistical Yearbook of Forestry. Statate Forest Sevice. Available online at:http://www.amvmt.lt/index.php/leidiniai/misku-ukio-statistika/2015

Design of Wood Wool Cement Board by Life Cycle Assessment method

Mario Marra[1,2], Stefano Guercini[2], Enrico Sgorlon[2]

[1] CNR IVALSA National Research Council, Trees and Timber Institute,

Via Biasi 75, 38010 San Michele all'Adige, Italy. marra@ivalsa.cnr.it

[2] University of Padova, Department of Land, Environment, Agriculture and Forestry, Viale dell'Università, 16, 35020 Legnaro, Italy

Keywords: LCA, ecodesign, Wood Wool Cement Board, inorganic binder

The energy efficiency for building heating has contributed to improve the use of insulating products. At the same time the demand for a reduction of the environmental burdens has led to a broad discussion about the sustainability of these building products. However, before these products can be called "sustainable", it is necessary to understand all the consequences involved and the real gains to the environment.

For an overall view of the environmental impacts associated with these products, Life Cycle Assessment (LCA) method has been ever more applied in searching answers to these questions.

The contribution of this study has been to quantify the environmental impacts produced by the manufacture of wood wool cement boards (WWCB). The environmental assessment has been combined with a technological analysis in order to verify the thermal performance of the insulation boards. The study has allowed to quantify the benefits of a short supply chain, recycled materials and different energy sources. Results have led to identify opportunities to improvement environmental performance of wood wool cement board manufacture through an ecodesign approach (Caprai *et al*. 2015).

WWCB consists of wood strands bonded within concrete matrix. It is produced in slabs, tiles, and building blocks for thermal and acoustic insulation of roofing, walls, and flooring. It is weather and fire resistant and has good thermal inertia and compression strength (Wang *et al*. 2016).

Life Cycle Assessment

A cradle-to gate LCA has been carried out and the system boundaries take place from log transport, wood working, mixing, board formation and shaping, drying and finishing operations, as well as the activities associated with the production of the raw materials, energy, and transport applied in the process. The functional unit has been expressed in mass because allows a better comparison with other insulating materials. The data for the WWCB manufacture has been collected on-site, while the secondary data has been provided by Ecoinvent v3, adapted to Italian conditions, and JRC ILCD databases. All assumptions has been owned by industrial partners and professional judgment. The case study site in Northeast Italy, is considered representative of the state of the art with 100 thousand m^3 per 40 thousand tons of boards. The ReCiPe Midpoint (H) v1.12 method has been used for impact assessment and data has been processed by SimaPro 8.0.5 software. According to this method, Figure 1 shows the impact amplitude of any single process to each environmental category.

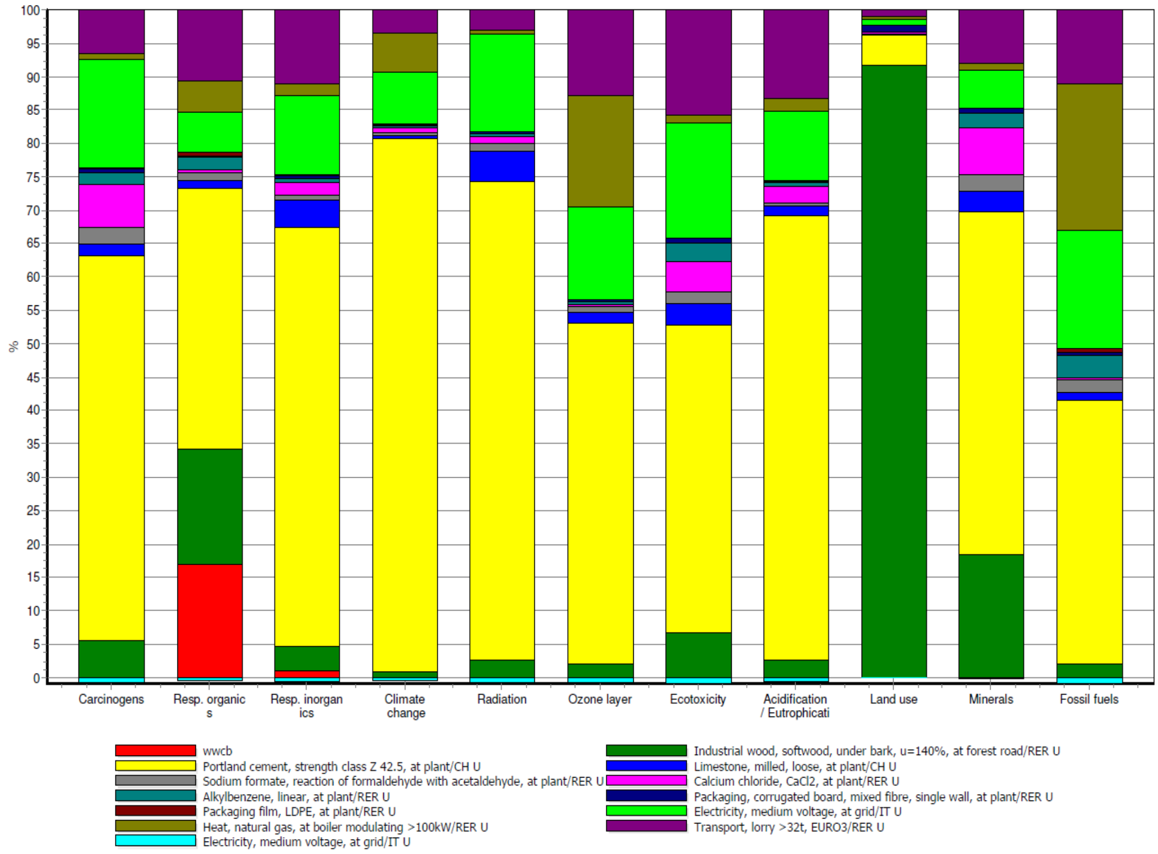


Figure 1: Life Cycle Impact Assessment of 1 kg of Wood Wool Cement Board

References

Caprai V., Doudart de la Gree G., Yu Q., Brouwers H. 2015. Design and performances evaluation of an eco-friendly board applying an alkali activated binder. In H-B. Fischer (Ed.). Internationale Baustofftagung, 16.-18. September 2015, Weimar, Bundesrepublik Deutschland. Vol. 2, 343-351

Wang L., Chen S., Tsang D., Poon C., Shih K. 2016. Value-added recycling of construction waste wood into noise and thermal insulating cement-bonded particleboards. Construction and Building Materials, 125, 316-325

Modified cellulose nanofibers thin-film as external layer for wood-based multi-layer composites

E. Robles[1], René Herrera[1], Grzegorz Kowaluk[2], J. Labidi[1]

[1] Biorefinery Processes Research Group, Chemical & Environmental Engineering Department, University of the Basque Country UPV/EHU, Plaza Europa 1, 20018 Donostia, Spain

[2] Warsaw University of Life Sciences, Faculty of Wood Technology, Nowoursynowska Str. 159, 02-787 Warsaw, Poland

*e-mail: jerobles001@ehu.eus

Keywords: 3-aminopropyl(triethoxysilane), cellulose nanofibers, multi-layered composites

This work was aimed to evaluate the performance of surface modified (CNF) obtained from almond shells as external coating for wood products. Cellulose was obtained through organic pulping and total chlorine free (TCF) bleaching sequence and cellulose nanofibers were defibrilated by mechanical methods, resulting in a green process to extract CNF straight from agricultural by-products. After cellulose extraction and size reduction, surface modification was done at room temperature in water/ethanol basis (50:50) with a cellulose/silane ratio of 1:2 the selected silane was a functional organosilane with alkoxy and amino groups (3-aminopropyl triethoxysilane) which acts both as coupling agent between cellulose nanofibers and wood samples as well as protective agent against moisture. After the modification, thin wet mats were done with solvent-casting method to achieve a stable and homogeneous surface, which was then layered on the surface of beech (*Fagus sylvatica* L.) wood veneers and hot-pressed in a Santec hydropneumatic moulding press with a curing pressure of 200 bar at 105 ˚C during 10 minutes. Surface topography (Figure 1) and surface energy were tested for the elaborated multilayered-composites.

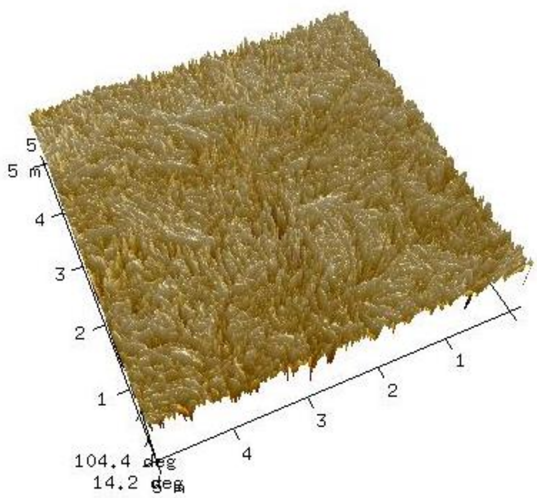


Figure 1. AFM topography of the modified CNF external layer.

Materials and Healthy Environments Research and Innovation Centre of Excellence (InnoRenew CoE)

Andreja Kutnar[1], Matthew Schwarzkopf[2], Michael Burnard[3]

[1] Andreja Kutnar, University of Primorska, Andrej Marušič Institute, Muzejski trg 2, Slovenia – 6000 Koper, andreja.kutnar@iam.upr.si

[2] University of Primorska, Andrej Marušič Institute, Muzejski trg 2, Slovenia – 6000 Koper, matthew.schwarzkopf@iam.upr.si

[3] University of Primorska, Andrej Marušič Institute, Muzejski trg 2, Slovenia – 6000 Koper, michael.burnard@iam.upr.si

Keywords: please provide a maximum number of 5 keywords here

The European Commission recognised the potential of a consortium of Slovene partners, led by the University of Primorska, and awarded it with a grant of almost 15 million Euros to establish the Renewable Materials and Healthy Environments Research and Innovation Centre of Excellence (InnoRenew CoE). The government of the Republic of Slovenia added 30 million Euros of investment funding to boost development of the new research centre.

The Centre of Excellence will pursue research, development, and innovation in renewable materials use, with a focus on supporting the circular economy and providing positive health benefits to building occupants.

The InnoRenew CoE will strive to become an international hub of scientific excellence in the field of renewable materials and human well-being in the built environment. The new centre of excellence will generate scientifically excellent original scientific research and offer business and RDI support to businesses and other institutions in Slovenia and abroad. With an extensive public engagement programme, the centre will target industry members, the general public, and policymakers to emphasise the importance of renewable materials use and sustainable development.

The underlying concept of the InnoRenew project is to develop and operate a new Centre of Excellence, InnoRenew CoE, that will conduct cutting edge scientific research related to renewable materials utilisation, develop industrially relevant applications of scientific developments and innovations, support businesses in their implementation of RDI activities and outcomes, and liaise with policy makers to direct more support to companies and research in the forest sector. The InnoRenew CoE's activities will be centred on two key distinguishing technologies that set it apart from other institutions:

- **Wood modification -** Addressing the mounting pressure on renewable resources and maximising the efficiency of materials derived from them requires new methods to improve the functionality, durability, properties, and environmental impacts. Wood modification methods (including thermal, thermo-hydro, thermo-hydro-mechanical, impregnation, etc.) will be investigated, developed, optimised, and then scaled up for industrial application in partnership with industrial actors.

- **REED** (Restorative environmental and ergonomic design). Building and product design today are balanced between function and form. Despite the existence of building design systems that attempt to minimise environmental impacts and provide greater societal benefits, they do not often incorporate scientific investigation of material and design decisions. REED extends these design systems and shifts the priority to maximising human health impacts in the built environment. REED achieves this by investigating the positive health impacts materials and design decisions have in the built environment, including ergonomic interventions for adaptability, safety, and accessibility, and ICT integrations to optimise building and district management. REED addresses the increasing demand for individual, healthy, and age appropriate products creating opportunities for industry to reach new markets by creating value through human-centric and user led design. The REED paradigm encompasses other aspects of sustainable design as well, including furniture, landscape structures (e.g., boardwalks, pavilions, etc.), household products, and other items that humans frequently interact with.

The InnoRenew CoE further refines and enhances its work by emphasising activities related to three core research themes: 1) Health - measurement of and work towards maximising positive human health impacts; 2) Design and Cultural Heritage - supporting designers, design topics, and cultural heritage impacts of material developments; 3) Policy - policy support to increase political, social, and economic support for research in the CoE's field and RDI implementation by industry.

The new centre of excellence will hire researchers in the areas of wood science, civil engineering, computer science, chemistry, health, business, and beyond. The interdisciplinary staff will bring together young scientists in a state-of-the-art research environment with leadership from global experts to develop their careers and advance wood science and sustainable building research to a new level.

Acknowledgments:

The authors acknowledge the European Commission for funding the project InnoRenew CoE (#Grant Agreement 739574) under the Horizon2020 Widespread-Teaming program, and infrastructure program IP-0035.