Performance Testing and Testing Methodologies

COST Action FP1303 *Performance of Bio-based Building Materials*

COST Action FP1404 *Fire Safe Use of Bio-based Building Products*

Book of abstracts from Joint Technical Workshop

Tallinn, Estonia — 4 & 5 March, 2015

Joint meeting of:

COST Action FP1303 “Performance of Biobased Building Materials”

COST Action FP1404 “Fire Safe Use of Bio-based Building Products”

COST FP1303
Performance of bio-based building materials

COST FP1404

Technical Workshop

Performance Testing and Testing Methodologies of Non-wood Biobased Materials

Tallinn University of Technology, Estonia

4-5 March, 2015

Book of Abstracts

Editors: Dennis Jones, Christian Brischke, Jaan Kers, Triinu Poltimäe and Joachim Schmid

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Book of abstracts of the joint Technical Workshop of COST Action FP1303 and COST Action FP1404 - Performance Testing and Testing Methodologies of Non-wood Biobased Materials.

Editors: Dennis Jones, Christian Brischke, Jaan Kers, Triinu Poltimäe and Joachim Schmid

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Disclaimer: This book of abstracts compiles the papers and posters presented at the Joint COST Action FP1303 and COST Action FP1404 meeting “Performance Testing and Testing Methodologies of Non-wood Biobased Materials” held in Tallinn, Estonia on 4-5 March 2015. The opinions expressed within are those of the authors and may not necessarily represent those of the hosts, the editors or the respective COST Actions.

About the cover photo

Tallinn University of Technology Library

The new TUT Library Building was completed in June 2009. Architects are Eero Endjärv, Priit Pent, Illimar Truverk and Mattias Agabus, interior design is made by Hannelore Kääramees and Kristi Lents. Name of the project is “AJUPUU” what can be explained as “Braintree”: library itself is a big tree with communications – stairs, elevators as a trunk and different floors and departments as branches. Books are made of paper what comes from trees and if we add the brain storming done in library while going through all those books we will get the “BRAINTREE”.

The new library building has unique exterior and interior design. In its protective grain-pattern composite textile covering it is one of the largest public buildings to employ this technique. The interior architectural concept is based on wood - the floor plan, the interplay of forms and the selection of materials. The use of bright green for the furniture, floors and walls, the use of wood as a material and the leaf pattern motif help foster the sense of a place, which is safe and pleasant.

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Foreword

COST FP1303 now finds itself in its second year. Through the high levels of activities between partners, we have had a successful first year, culminating in an excellent conference in Kranjska Gora, Slovenia. I felt that those present at that meeting were equally impressed with the variety and quality of work ongoing across Europe and the lively discussions will no doubt lead to many new projects dealing with the performance of bio-based materials.

So, we start year 2 with a meeting in Tallinn, the capital of Estonia, with our hosts from the Tallinn University of Technology. The university, founded in 1918 by the Estonian Engineering Society is the only technical university in Estonia. During the meeting we will get the opportunity to visit the near zero building and climate chamber at TUT. We will also have the opportunity to visit the Estonian Open Air Museum, a life-sized reconstruction of an 18th-century rural/fishing village, which comes complete with church, inn, schoolhouse, several mills, a fire station, twelve farmyards and net sheds. The site spans 79 hectares of land and contains 72 separate buildings and is located 8km to the west of Tallinn city centre at Rocca al Mare.

This meeting aims to focus on “Performance Testing and Testing Methodologies of Non-wood Bio-based Materials”, and will include a first link with another COST Action – FP1404 “Fire Safe use of Bio-Based Building Products”. When FP1303 was approved, there were questions regarding fire performance, to which we indicated this would be the subject of another COST Action application. Through the efforts of Joachim Schmid of SP Technical Research Institute of Sweden, this has become a reality. This meeting will see the first of hopefully many interactions between FP1303 and FP1404.

In total, this meeting will comprise 20 oral presentations and 21 poster presentations. I am looking forward to this meeting in Tallinn, which has only been possible through the hard work of the Local Organising Committee, particularly Jaan Kers and Triinu Poltimäe. Without their help, this meeting would not have been possible. On behalf of COST Actions FP1303 and FP1404, I thank them for their efforts.

I would also like to thank all the speakers and Action members that are coming to Tallinn, as it is they that make these COST Actions a success. I also wish to thank COST for their funding of these Actions, providing the opportunity for discussion and collaboration, particularly between Early Stage Researchers and their scientific peers.

I hope all participants enjoy the scientific content presented during the meeting and continue to build the ever growing network in the area of performance of bio-based building materials as well as forging new links in areas related to fire safe use of bio-based building products.

Dennis

Dennis Jones

Chair, COST Action FP1303

Preface

Estonia is rich of forests, 51.1% (2.2 mln ha) of the total area is covered with the forest which gives us 5th place in Europe in terms of percentage forested land area. The growing stock forms 450 mln m^3. The distribution by tree species is following: pine 30.3%, spruce 23.4% and birch 22.9% followed by aspen 7.4%, grey alder 7.1%, black alder 4.9% and others 4%. Pine- and spruce logs have been used for construction of traditional log houses with thatched roof for many centuries. Estonia has become the biggest exporter of wooden houses in the EU. In 2013, the total export value of wooden houses was € 202.4 mln. Wooden houses are classified as: timber frame homes, modular homes, prefab homes, machined log homes, handcrafted log homes and garden houses. Forestry, sawnwood, wooden frames, wooden houses and furniture products manufacturing industry (over 6000 companies and 35000 employees) forms 22% of GDP of the processing industry in Estonia. Total export of wood based products in 2013 was € 1.6 billion.

Forestry, woodworking and furniture industry needs R&D specialists from the universities. Estonian University of Life Sciences has a long tradition in conducting research and educating specialists in silviculture and forestry. Industry was the main driving force for starting with the woodworking curriculum on 1976 and establishing the chair of woodworking in year 1979 in Tallinn University of Technology.

Energy efficiency of buildings is one of the key topics for near future. Passive houses and near-zero buildings should become more popular in Estonia. To increase the use of wood and other bio-based materials in construction of houses in public and private sector is one of the aims for Estonian forestry and woodworking industry. Wood and other bio-based materials in building and construction sector are facing severe price competition with concrete and oil-based products. There are still some preconceptions related to wood based products fire safety and fire performance, moisture adsorption and bio-resistance properties of bio-based materials which we need to overcome to use more bio-materials in building and construction sector

The joint workshop of COST ACTIONS FP1303 and FP1404 in Tallinn is intended to discuss recent research and development work about bio-based building materials performance and durability. Special test houses with implemented testing methodologies for energy-, thermal-, ventilation- and weathering analysis of wall constructions and buildings will be visited during the workshop to put theory in practice. Visiting the Mektory the innovation and business centre of TUT would give participating scientists new brilliant business ideas for establishing start-ups. Bio-based building material durability can be assessed in the 2nd seminar day which will be held in the famous Estonian Open Air museum. Surrounding historical wooden houses are giving us good and comfortable environment to discuss the promising future of bio-materials.

We are very pleased to host COST FP1303 and FP1404 joint meeting in Tallinn 4-5th March 2015.

Local organizers

Jaan Kers, Triinu Poltimäe

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Testing of durability of bio-based non-wood composites

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Keywords: durability, decay, mould, bio-based composites, tests

During the last decade there has been increasing research and development activities going on with natural fibre containing sustainable composites. The drivers for these composites are new environmental laws and regulations, need for CO_2 neutral materials, increasing pollution and increasing demand for bio-based materials. Natural fibres from annual crops (*e.g.* flax, hemp, jute), animal, grasses, leaves or wood are now commonly used as reinforcements or fillers in various applications.

Biological resistance of the modified flax fibre – bio-epoxy polymer composites was studied using an accelerated laboratory decay test in terrestrial microcosms and mould test in a chamber at high relative humidity (Figure 1).

Figure 1. An overview of the terrestrial microcosmos test "TMC" (left) and mould test in high humidity (right).

Fibre polymer composites were cut to a size of 13x154x3 mm and pine sapwood reference specimens were 10x100x5 mm. Before the experiment all the specimens were dried at 80 ^{o}C for three days to measure the dry weight and moisture content of the specimens. Test specimens were embedded to the soil so that 20 mm of the specimens were above the soil surface. Test chambers were incubated for 12 weeks and 16 weeks in a conditioning room at +22 ^{o}C and 75% RH. The mass loss of each specimen was calculated as a percentage of the initial dry mass. MOE and MOR were analysed after test.

Results showed that soil was bioactive and 8% of mass loss in untreated Scots pine sapwood (reference) specimens were observed after 16 weeks' incubation and presence of soft rot was observed according to the microscope analyses with method described in the standard ENV 807. Differences in mass loss between differently modified flax fibre polymer composites were observed. Mass loss of 5.6% to 9.2% was observed between modified composites and 9.6% in unmodified composites after 16 weeks' incubation period. These results are similar to modified wood-plastic composites that showed 5-8% mass loss after 16 weeks in soil block test (Segerholm and Ibach 2013). In the present study BTCA treated composites showed most resistance to decay from the differently modified composites and composites treated only with NaOH were damaged the most with 9.2% mass loss detected. Similar results were also achieved with nonwoven coir or oil palm fibre composites where water and biological resistance properties of composites were improved by modification with methacryloxymethyltrimethoxy silane (Hill and Khalil, 2000). Average modulus of elasticity (MOE) (tensile strength) loss percentage after 16 weeks' incubation varied between 29% and 53% in modified composites and 59% in unmodified composites. Pine sapwood showed 33% MOE loss percentage in average.

After six weeks' exposure in high humidity conditions, highest visual mould growth was observed in the unmodified composite and pine sapwood specimens.

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An overview of the test methods used to assess the resistance of bio-based building materials against subterranean termites and other insects

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Keywords: test methods – durability – resistance – termites - insects

Bio-based materials often contain sugars and nutrients which can attract various insects and/or promote their settlement and reproduction. Some of the insects found in such materials are well-known wood borers such as termites, which can deal with any kind of material containing cellulose, or coleopteran larvae, which sometimes manage to invade non-wood materials directly in contact with wood. Other groups of insects, such as carpenter ants, can settle down in loose fill insulation materials and alter their thermal performance, and various species of bees and wasps are able to dig galleries and lay eggs in all kinds of building materials.

Subterranean termites are well-known pests which can destroy man-made structures containing cellulose-based products such as wood, paper and cotton. They can also damage a broad range of non-cellulosic building materials which they may encounter while foraging for food either underground or inside buildings, such as fibre-based panels, insulation materials, electric sheaths, plastic water pipes or bricks made of concrete mixed with bio-based raw materials. In countries affected by infestations of termites, buildings and building materials should be protected against termites either naturally or by using biocides.

Because certain building materials are not visible or accessible anymore once the structure's construction is completed – *e.g.*, thermal insulation materials placed under the structure's basement or buried water pipes – it is important to ensure that these materials can resist termite attacks and perform as expected.

European standards have been designed to supply the wood sector industries with laboratory and field methods which can be used to assess the resistance of untreated and preservative-treated wood. However, neither Europe-wide nor national standardized protocols are currently available for determining the resistance to termites of construction materials other than wood. The FCBA Laboratory of Biology/Entomology has specialized for more than 20 years in testing the resistance of various materials against subterranean termites belonging to the genus *Reticulitermes*, which naturally occur in all countries if southern Europe (Portugal, Spain, France, Italy, Croatia, Slovenia, Greece, and Turkey). Many different test protocols have been designed and are used nowadays both under laboratory and field conditions to assess the resistance of building components made of different raw materials, such as panels, insulation (Fig. 1), cables, polymers, bricks, or bamboo-based products. Test methods have also been defined for assessing the effectiveness of additives meant to repel or attract termites, such as traditional biocides, adhesives, fire retardants, or natural plant extractives.

Figure 1: Subterranean termites foraging into bio-based insulation material

An overview of both laboratory and field test protocols used to assess the resistance to termites of non-wood bio-based materials is presented and their relevance discussed. Some of the most frequently used approaches shown are choice tests, force-feeding tests, crossing-through tests, and assessment of attractive, phago-stimulating and repellent effects (Fig. 2).

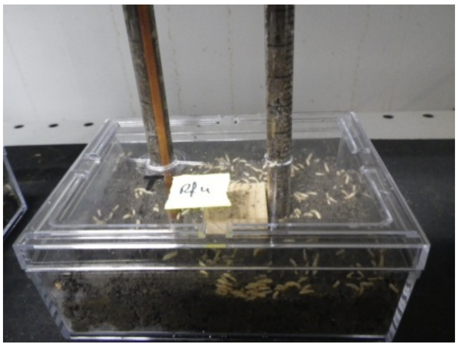

Figure 2: The test device used to demonstrate the attractive or repellent effect of natural plant extractives on subterranean termites

References

Method CTBA-BIO-E-043 Adaptation of EN 117 standard to determine the termite resistance of a material

Method CTBA–BIO–E-044-3 Resistance of cellulose-based insulation materials against termites

Recent timber constructions in Italy: General characteristics, qualities and faults based on cases study

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Keywords: Cross laminated timber, glue-lam, wooden structures, performance, durability

Wooden building and structures became more and more popular in Italy since 1980. First, the large-span glue-lam structures have been utilised for public structures such as indoor sports ground, shopping malls, auditoria, bridges, monuments, where the long and large glue-lam beams can cover huge area. In the meanwhile, they also allowed architects (sometimes called archistars) to design and build impressive structures, also from the aesthetical point of view.

During last ten years, another constructive technique has been used, based on the cross laminated timber (CLT). CLT Panels and beams are generally of Austrian – German production and are made of Norway spruce (*Picea abies*) without any treatment to artificially improve their durability because their use is previewed in class 1-2 according to the standard EN 335: 2013. Indeed, being under cover, theoretically they shouldn't suffer from fungal attack, but any building could have hidden, dangerous moisture traps.

This presentation, based on different cases across Italy, tries to summarise the Italian situation on modern timber buildings and analyse the advantage of increasing the wood use without hiding the most important critical aspects. The analysed cases have been inspected always for occurrence of decay or failure, but this fact does not mean that all the Italian modern wooden structures are decayed or not well-designed. For this reason we also show some current (not historical) good examples of wood utilisation.

Fig. 1 Pope cross, failed in 2014

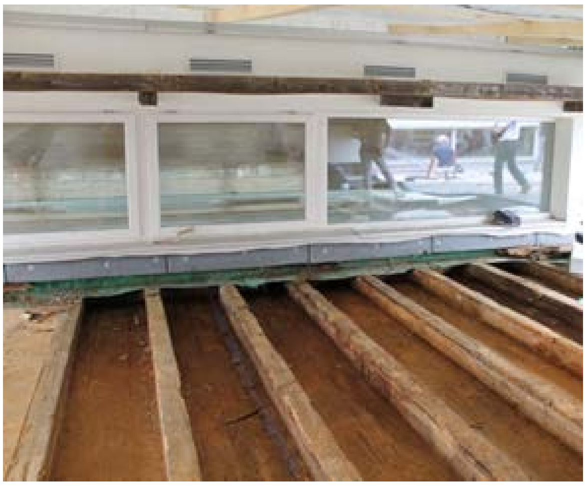

Fig. 2 CLT building and glue-lam beam roof

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

Development of a laboratory testing concept for whole bio-based wall components against fungal colonisation.

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Keywords: Biobased, building material, moisture, fungi

Preformed modular walling units are becoming an established building method. These utilise a composite structure including sheathing and insulation materials which may include a range of bio-based materials such as timber, wool or straw. This method of production and building has a number of advantages and disadvantages over traditional building methods. For example it is well known that organic materials may be susceptible to attack from a range of fungal organisms and any biobased material used in locations where there is the possibility of microbiological activity must be expected to be able to withstand or prevent such attack. There are a wide range of test methods and standards in place to test susceptibility although most of these test individual components such as the wall panel material. There have been investigations into the performance of wall designs on a large scale in service and in large chamber tests, though the large chamber investigations rarely test for decay.

One necessary condition for fungal colonisation is the level of water present – generally in wood for example a minimum of 18-20% moisture content is required for fungal growth. A great deal of work has looked at durability of natural materials but again generally as individual samples. Little work has been done to determine whether combining materials may have an effect on the ability of fungi to colonise them.

Vapour sorption testing gives good data on the moisture profile of materials under range of relative humidity conditions. Data for wood panels for example (see Figure 1) shows that even at high RH values the moisture content (17%) is unlikely to be high for fungal growth. Under the same conditions however, the moisture content of a wood based fibre insulation is much higher (30-40%) and easily within the range at which fungal growth is likely.

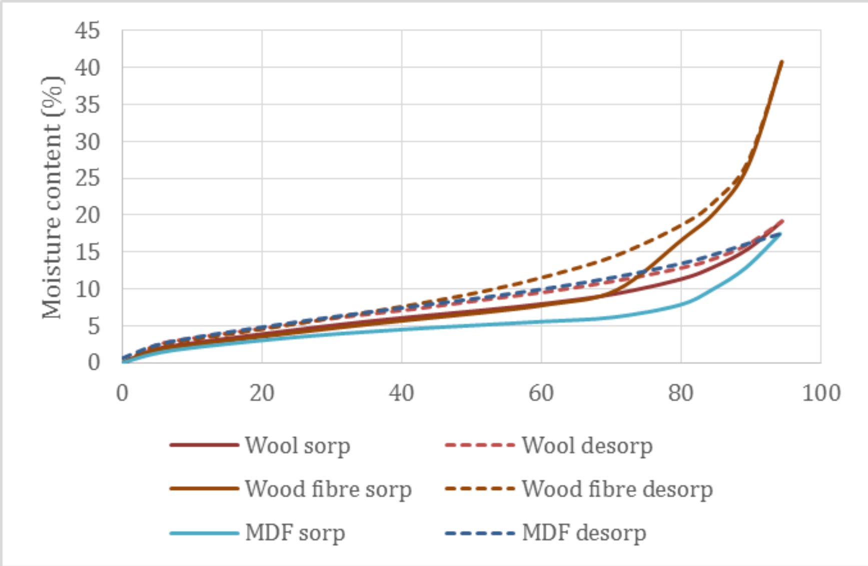

Figure 1: Relative humidity dependent Isotherm moisture content of MDF, Wool and wood fibre insulation.

Another factor may be the ease in which water is able to move though a material. Whilst generally the addition of insulation does not increase the incidence of microbiological it is possible to envisage scenarios where not only is the insulation material itself susceptible to attack but it may also act as a moisture reservoir or feeder strip for the sheathing and/or structural components. As part of the development process of new wall component systems a method of testing materials together could be useful in identifying susceptibilities which may later arise.

This presentation details hygric and moisture based studies of some building materials and explores the development of the concept of laboratory testing of samples of whole wall components.

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Model house for monitoring of performance of wood and quality of insulation envelope

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Keywords: natural durability, thermally modified wood, copper-ethanolamine, moisture content, temperature

Model house in Ljubljana was build according to the building practice in central Europe. Similar constructions are used for commercial houses as well. The house's timber frame based construction was made of Norway spruce wood, and outside insulated with low density wood fibre boards (Figure 1). The compartments in the timber frame construction were insulated with loose-fill cellulose fibres (Zimicell). Construction was covered with watertight and vapour–open membrane. For roofing wooden shingles made of spruce, thermally modified spruce, wax treated thermally modified spruce and copper-ethanolamine treated spruce are applied. Wooden façade has protective and aesthetic role. It is made of 22 different materials, that are used for this and similar application in this region. Façade elements are positioned horizontally and screwed on the vertically positioned Cu-ethanolamine treated wood elements. Beside untreated wood (spruce, larch, beech, English oak, sweet chestnut, Scots pine sapwood and heartwood, lime, ash), 4 different treatments were applied to the materials; copper-ethanolamine impregnation (Silvanolin®), montan wax impregnation (Silvacera®), acrylic surface coating (Silvanol® Lazura B), and thermal modification (Silvapro® Wood). Cross-section of the façade elements is 2.5 × 5.0 cm. Decking in front of the house was made of the same materials. There are two windows (one roof window by Velux, and the second one was made of thermally modified and unmodified spruce by company M Sora). Door was made of thermally modified wood as well. Façade on the model object was finished in the mid of October 2013.

The model house has multiple purposes. The prime objective is to monitor aesthetical properties (aesthetic service life), presence of decay (functional service life), cracks formation and moisture performance. Further objectives are related to monitoring of insulation properties of different materials used for construction, thermal conductivity, phase shift and formation of volatile organic compounds and formaldehyde is determined. There are different sensors applied in respective model objects. The majority of the sensors was produced by Scanntronik (Germany). For moisture measurements, resistance sensors are applied on 120 positions and linked to Gigamodule that enables wood MC measurements between 6% and 60%. Temperature is monitored on various wooden materials, and on different layers of the construction. Furthermore, temperature is determined on the surface of window, walls… There are 70 sensors positioned all over the building. Temperature is logged with Thermofox data loggers. In order to determine relative humidity of air on various micro-locations within building 10 Higrofox sensors are positioned within building and terrace. Thermal conductivity of different materials is monitored with 8 Hukseflux sensors (HFP01) and logged with system based on CR1000 (Campbell Scientific). Formaldehyde content and VOC concentration in air is determined with Haarla based system. Logging intervals varies between 5 min (Heat flux), 1 h (temperature, RH) and 12 h (MC). Every year there is approximately 500,000 values recorded. In parallel to automated system, colour changes, presence of blue stain fungi and degradation is determined several times per year as well according to the slightly modified relevant standards. Weather station Davis is positioned next to house in order to obtain accurate weather information. In the respective year, it is planned to install sensors that will enable determination of wind driven rain and condensation from the air on all respective façade walls.

Fig. 1: Skeleton construction (left) and freshly installed façade (right) of the model house in Ljubljana.

As this house has a long term potential, it is expected that the most valuable results will came out after few years of monitoring. However, the first results clearly indicate influence of the orientation, construction measures, overhanging on the MC of wood (Figure 2).

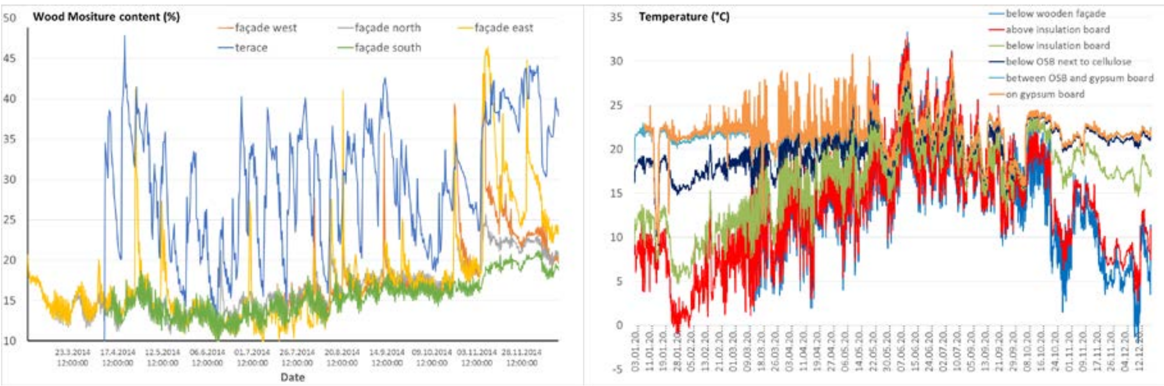

Fig. 2: Influence of the position in the house on MC of spruce wood and temp. distribution through the wall.

Acknowledgments: The authors acknowledge support of the Slovenian Res. Agency within the project L4-5517 and programme P4-0015. Operation is partly financed by EU, European Regional Development Found support of the Research voucher - Silvaprodukt d.o.o. and Research voucher –Zimic.

Assessment of subterranean termite symbiotic fauna under different diets

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Keywords: subterranean termite, symbiotic flagellate protist, control strategies, wood protection

Subterranean termites are known as serious pests of wood, having highly efficient lignocellulose degradation ability which largely relies on flagellate protist symbionts present in the hindgut. It is clear that the symbiotic association between lower termites and their hindgut symbionts have advantages for both, since the termites are able to receive an extra energy supply resulting from lignocellulose degradation, while hindgut symbionts have shelter, protection and food, supplied by the termite host. Termite gut microbiota and respective cellulosic activity may be a strategic target for designing molecular-based bio-pesticides for termite control. For such an innovative strategy, the characterisation of the flagellate protist symbiotic fauna should be pursued.

The effect of different diets on termite flagellate protists community of the lower termite *Reticulitermes grassei* (Clément), the principal subterranean termite species in Portugal, was investigated. The main objectives of this STSM were to obtain high quality microscopy images of flagellate protists and to assess the correct methodology to perform a transcryptomic analysis of flagellate protists.

Termites were collected in Portugal and offered six different diets (natural diet (pieces of the wood from where they were collected), pine wood (*Pinus pinaster* Aiton), European beech (*Fagus sylvatica* L.), thermally modified beech (submitted to 180 ^{o}C during 4 hours), cellulose (cellulose powder mixed with deionised water) and starving (no source of cellulose offered to the termites) for 14 days. After this trial, termites were evaluated in terms of flagellate protists diversity and abundance and prepared for microscopical and molecular analysis.

The results obtained showed clearly that termite flagellate protist communities living inside their hindgut change according with the type of diet. The RNA and DNA extraction techniques experimented, although not as successfully as expected, were a step forward towards the optimization of the methodology to be applied to achieve good quality samples for further analysis. The use of Transmission Electron Microscopy enabled the first visualisation of flagellate protists from *R. grassei* hindgut, allowing the further analysis of their internal physiology, important for their correct identification.

The search for new wood treatments and biobased materials must take into consideration their resistance to biological degradation agents, as subterranean termites. On the other hand, further knowledge of the effect of the different products on the symbiotic interactions on the termite gut might lead to interesting developments in future termite control.

Acknowledgments:

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Fire safe use of bio-based building products – a new COST Action FP1404

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Keywords: fire safety engineering, material science, structural engineering, combustibility

Introduction

Bio-based building products have a very long history, *e.g*. as timber structural members. Combustibility was the main reason why bio-based building materials were banned from many applications. When *Performance Based Design* (PBD) became possible many building regulations opened the market for bio-based building products. However, large differences between regulations in countries exist and the use of combustible building products is still very limited (*e.g*. in Spain bio-based insulations can be used up to a building height of 18 m while it is limited to 7 m in Germany).

Modern living offers attractive, flexible buildings and aims for cost efficient building techniques. Sustainability of building products has become an important issue. Consumers demand renewable products; however the Fire Safety of the end-product has to remain on a high level. During the last decade the portfolio of building products made from bio-based raw materials has increased enormously. The material properties affecting a possible fire development vary which has been confirmed in many development projects.

Future of Bio-based building products

Fire Safety Engineering (FSE) may be a tool to address high fire safety levels for combustible building products, in recent years FSE has found large acceptance in many countries. FSE allows a PBD with customised building solutions. FSE can be defined as the application of scientific and engineering principles to the effect of fire in order to reduce the loss of life and damage to property by quantifying the risks and hazards involved and provide optimal solution to the application of preventive or protective measures (INSTA 950). However, the available techniques are often limited to non-combustible materials.

Required engineering competence

The determination of building specific fire development (fire load), evacuation needs and active fire safety measurements (*e.g*. sprinklers) is normally covered by *fire safety engineers* while *structural engineers* design the load-bearing structure only disregarding their possible interaction with the global building design. Both professions are struggled with a large variation of regulations regarding material restrictions and load-bearing performance requirements in different regions and countries. *Material scientists* are deeply involved in the development of new products but are rarely aware of boundary conditions given in building regulations and field of applications. Therefore, the COST Action FP1404 offers a networking platform for

i) fire safety engineers,
ii) structural engineers and
iii) material scientists.

Fields of the COST Action

There are several research questions which have to be solved for the application of FSE tools and combustible building products and get closer to a harmonised European market. In principle, the challenges are connected to the different stages of a fire development which are initial development phase,

> In the first phase of a fire (development or growing phase) the material characteristics of surfaces exposed to fire are important. Materials contribute to the fire development in different ways. Today, materials are tested and according to EN 13823, EN ISO 11925-2 and EN ISO 9239-1 and classified according to EN 13501-1. The non-linear classes describe the *Reaction to Fire* of building products. In building regulations different rules for surface materials are specified depending on the use and type of the building. This area affects mainly fire safety engineers and material scientists.

> The next phase after flash over when the fire is fully developed, the overall structural performance has to be verified by testing or calculation (burning phase). An important input parameter to estimate the response of elements is the fire development (fire curve). However as soon as the fire curve is deviating from the “standard fire curve” (compare EN 1363-1), verification becomes complex or impossible. In this phase the compartment temperature is more homogeneous and the fire can be ventilation controlled (limited oxygen available) or controlled by the fire load (limited fuel available). Severe fires are often the first type of fires. When combustible gases cannot burn inside the compartment they ignite exterior near the façade.

> The last phase is the decay phase when the fuel is consumed and temperatures fall. For compartments with combustible surfaces and insulation it is today not clear if and when they will reach a burn-out, this is when all fuel (*e.g*. furniture) is consumed and only the structure itself is left.

Work within FP1404 will be organized in a WG for Dissemination as well as in three technical WGs:

WG1 Contribution of bio-based materials to the fire development
WG2 Structural elements made of bio-based building materials and detailing
WG3 Regulations for the fire safety of bio-based building materials

Bio-based building materials - demands on the reaction to fire performance

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Keywords: bio-based materials, reaction to fire peformance, combustibility, material science

Introduction

Our forests are a naturally renewable resource that has been used as a principal source of bioenergy and building materials for centuries. The growth of world population and affluence has resulted in substantial increases in demand and in consumption for all raw materials. Resulting increases in demand for wood and other bio-based products provides a unique opportunity for developing new generations of renewal, sustainable and materials efficient bio-based composites. But as most of the bio-based materials are combustible the use as building materials is limited due to the building regulations. Performance-based design (PBD) is a newer development in fire protection engineering and many building regulations opened the market for bio-based building products since PBD became possible. By knowing the necessary fire behaviour of building materials *e.g*. ignability, flame spread, heat release rate *etc*., the performance-based design can be used to demonstrate similar fire safety level as by using non combustible or limited combustible products. On the one site limited information on the fire behaviour respectively fire performance parameters of bio-based building products is available and on the other hand the knowledge how to protect the material from burning needs further research. The *WG1* within the *COST FP 1404* will investigate bio-based materials concerning fire behaviour and extend the knowledge about possibilities to increase the reaction to fire class from bio-based building materials.

Use of bio-based materials in buildings

Although there is no existing official definition, it is commonly admitted that bio-based materials are materials issued from potentially renewable resources, *i.e*. from vegetal or animal origin. There are over a hundred listed bio-based materials for use in buildings. One can cite hemp, flax, cellulose, straw, cotton, cork, coconut, sugar beet, wood, casein, corn, jute, kenaf, marine biomass, grass, sisal or henequen, ramie, abaca, broom, kapok, raffia, bamboo, reeds, rushes, silk, sugar, wax, citrus distillates, pine needles, feathers, sheep wool, *etc*.

Building products must meet the requirements stated by regulations. The use of wood and biobased materials is popular, especially for visible surfaces, but this may cause risks under fire exposure.

Performance based design (PBD) offers methods in using combustible building products also in buildings in which, by using previous verification methods, this was not possible. However, due to limited information on the fire performance of bio-based products and dependent on the experience of the fire safety engineers the use of combustible building products is still very little. Additionally the different national regulations differ widely and limit the use of combustible biobased materials in buildings.

Depending on their usage in buildings, three main categories of products can be distinguished, corresponding to their technological functions:

1. Thermal insulation or/and acoustic - The first and most is the thermal insulation and/or acoustic insulation. For the insulation function, there are a large number of materials made out of plant fibers associated with a synthetic or biobased polymer binder. Fibers are first treated and combined with polymers binders (up to 25%) ensuring materials cohesion. Synthetic-based binder products are found on the market as wool rolls or rigid or semi-rigid panels. Bio-based binder products are still at a development stage. Insulators can be also found as compacted straw blocks without additives. Bio-based materials can also be found as aggregates and, to a lesser extent, as plant fibers combined with inorganic binder containing lime or clay.

2. Supporting structures - This usage category includes wood, straw blocks and self-supporting blocks based on hemp. Wood is already on the market, while the two others are still at research stage.

3. Multi-functional construction elements - Materials such as synthetic matrix composites or partially bio-based composites reinforced with plant fibers can have various applications: windows profiles, cladding, noise barriers, decking *etc*. Some of these multifunctional materials are in research and development phases whereas others are already in the marketing stage (Ventura 2012).

With regard to the use of the bio-based building materials dependents on the use, different requirements on the fire behaviour of building materials has to be fulfilled which are defined in national regulations and determined by the reaction to fire classification according to EN 13501-1.

Fire behaviour classification system in Europe

The 2011 "Construction Products Regulation (CPR)" (EU 305/2011) has the purpose to allow the free trade of construction products in the EU. It deals with types of products and includes seven Basic Works requirements, which have to be met by a construction product to obtain a CE-Mark. Details are covered in interpretative Documents (*i.e*. Essential Requirement "Safety in Case of Fire"). In all 28 EU Member States, the CPR requests harmonised fire classes (Euroclasses) and tests.

The European reaction to fire classification and testing system is mandatory for all Member States. However, the fire safety regulations of the single Member States and the fire safety levels laid down therein are not part of European harmonization and remain the responsibility of the Member States.

The European classification standard EN 13501-1 ranks construction materials in 7 classes with regard to their fire behaviour: A1, A2, B, C, D, E and F.

- A1 and A2 represent the two degrees of non-combustibility and limited combustibility
- B-E represents products that may go to flashover in a room and at certain times
- F means that no performance is determined

- Additional classes of smoke production (s1 to s3) and of flaming droplets/particles (do-d2) have also been introduced.

In general, 5 different test methods are used to determine these classes:

- EN ISO 1182: Reaction to fire tests for building products - Non-combustibility test
- EN ISO 1716: Reaction to fire tests for building products - Determination of the heat of combustion
- EN 13823: Reaction to fire tests for building products - Building products excluding floorings exposed to the thermal attack by a single burning item
- EN ISO 9239-1: Reaction to fire tests for floorings - Part 1: Determination of the burning behavior using a radiant heat source
- EN ISO 11925-2: Reaction to fire tests - Ignitability of building products subjected to direct impingement of flame - Part 2: Single-flame source test.

However, simulations need also information on essential parameters *e.g*. heat release rate, time to ignite, mass loss *etc*. For these parameters additional methods have to be performed for generating valuable data in assessing contribution to fire, the influence on movable contents fire loads (such as furniture) and fixed fire loads (such as wooden linings and structural elements) need to be taken into account as well as the influence of protective linings/claddings.

Objective of COST ACTION FP 1404 WG1

Main objectives of *COST ACTION FP1404 WG1, Contribution of bio-based materials to the fire development*, are the following:

1. Determination of the reaction to fire performance of bio-based materials and products
2. Investigation of interaction of bio-based materials and products with fire
3. Development of methods and treatments for improving fire performance.

For extending the available wood based experimental date and information needs to be reviewed to make it suitable to other bio-based materials. Much information on the reaction to fire performance is still available on wood and wooden products, but some gaps have to be closed with additional investigations.

Concerning the interaction of bio-based materials and products with fire limited information is available. One main objective is to acquire scientific knowledge in order to develop performance criteria and compare different perspectives to enable extended and fire safe use of existing and new bio-based materials. For this within the COST ACTION FP1404 suitable methods and standards will be compared and defined in collaboration with the WG2-Structural Elements of bio-based building elements and detailing and WG3 Regulations for fire safety of bio-based building materials. A database will be generated on the fire performance of BIO-Based Building Products.

One focus will be on the fire protection ability of bio-based materials and construction which will be assessed. Additional the necessary level of fire protection required to bio-based materials (especially insulations) and structures will be investigated and recommendations elaborated.

Combustibility of bio-based materials is still one of the challenges, which have to be optimised. Modification methods to decrease the combustibility of bio-based building materials will be collected and assessed.

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EN ISO 1182: Reaction to fire tests for building products - Non-combustibility test, European Standard, 2010

EN ISO 1716: Reaction to fire tests for building products - Determination of the heat of combustion European Standard, 2010

EN 13823 Reaction-to-fire tests for building products – Building products excluding floorings – exposed to the thermal attack by a single burning item, SBI test, European Standard. 2011

EN ISO 9239-1 Reaction-to-fire tests for floor coverings – part 1: Determination of the burning behavior using a radiant heat source. European Standard. 2010

EN ISO 11925-2 Reaction-to-fire tests for building products – Ignitability of building products subjected to direct impingement of flame – Part 2: Single-flame source test. European Standard. 2011.

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Structural elements made of bio-based materials and detailing – WG 2 of Cost Action FP1404

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Keywords: Structural elements, bio-based materials, fire resistance, fire behaviour, combustibility

Bio-based building products, *e.g*. as sawn or engineered timber structural members, have a very long history in the built environment. Historical fires led to combustibility being the main reason why bio-based building materials could not be used in many applications, particularly in dense urban centres. When performance based design (PBD) for fire became possible, during recent decades, many national building regulations effectively opened the market for bio-based building products. However, large differences between building regulations in different countries still exist, even within Europe, and the use of combustible bio-based building products is still relatively limited; particularly in multi-storey building construction. Whether this is because the prescriptive guidance is irrational and/or out-dated, or because legitimate fire safety concerns exist, is not well known in many cases.

Fire Safety Engineering (FSE) has achieved increasing acceptance in recent years; it allows a PBD with customized building solutions. However, the available tools, guidelines, and engineering techniques are often limited to non-combustible building materials. Knowledge of the performance of many bio-based building materials and systems under the non-standard fire scenarios, which might need to be considered during a rational PBD assessment of a building, is relatively poorly developed, and this hinders PBD in many cases for these materials.

Fire resistance classification systems of structural elements under so-called 'standard' fire curve exposures are well established and commonly used for most cases. However, a common database on structures fulfilling certain fire classes needs to be established. In addition, in real life the use of the Eurocodes' parametric/natural fires may be very important for both safety and efficient/sustainable structural design. For this reason, the related material property data and fire protection methods need to be gathered and reviewed. In addition, guidance and best practice on detailing in construction (*e.g*. penetrations, cavities, connections, *etc*.) are of paramount importance to ensure adequate fire safety.

From previous research projects on wood-based products, there already exists a wealth of information that is available from various sources. However, this information needs to be first compiled and reviewed, so that it can be modified and applied, potentially to other bio-based materials.

Working Group 2 (WG2) of Cost Action FP1404, *Structural elements made of bio-based materials and detailing*, deals with producing a database of available knowledge as well as new information on material properties, structural response, and fire protection schemes for bio-based materials and construction systems in different credible fire scenarios both in and around buildings. The main activities to be undertaken include:

a. developing and perpetuating an improved understanding of the structural response, and hence fire resistance, of bio-based structural elements and materials exposed to a range of 'standard' and realistic (natural) fire scenarios;

b. characterising the reactive, thermal, and mechanical material properties of relevant bio-based building materials (and fire protection methods) so as to enable, by use of fire engineering and rational engineering judgement, their use in building applications which might otherwise be prohibited by prescriptive fire safety regulations;

c. developing and disseminating databases of information on the performance of both bio-based structural elements and construction materials relevant to points (a) and (b) above; and

d. studying the effects of construction detailing and structural connections of various types for achieving fire safety in a bio-based built environment.

This WG2 will closely work together with the standardisation body CEN TC 250/SC 5 "Eurocode 5 – Design of Timber Structures" who are currently working on a revision of Eurocode 5 (EN 1995-1-2), expected in 2020. The outcome of WG2's activities will serve as an important evidence base for the envisioned revision.

Further, the collaboration between the two Cost Actions FP1303 and FP1404 is critically important, since FP1303 can provide both basic and reaction-to-fire information on a large variety of bio-based building materials and systems; all types of bio-based structural and building materials require defensible fire design methods for their safe, efficient, and confident application in real projects.

Acknowledgments:

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Regulations and standards for fire safety - FP1404 WG3

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Keywords: fire safety, standards, regulations, fire safety engineering, bio-based materials

Construction Products Regulation (CPR) contains seven basic requirements. Safety in the case of fire is one of these requirements, and defined as follows:

- the load-bearing capacity of the construction can be assumed for a specific period of time;
- the generation and spread of fire and smoke within the construction works are limited;
- the spread of fire to neighbouring construction works is limited;
- occupants can leave the construction works or be rescued by other means;
- the safety of rescue teams is taken into consideration.

These requirements are implemented and further detailed in European standardisation and in national regulations.

The European fire classification system includes reaction to fire of building products (contribution to fire/heat release levels, smoke production and burning droplets/particles), fire resistance of structural elements (load-bearing capacity, separating function and insulating performance) and external fire performance of roofs. These testing methods are not material specific and performance levels (fire classes) are as results.

Requirements for fire safety in national regulations have to use the European fire classes (no national classes allowed), but there is a freedom to select among the available classes and to choose national safety level accordingly.

The general principles and levels of regulatory tools concerning fire safety are shown in Fig. 1. Either pre-accepted design using fire classes and numerical values (prescriptive regulations), or performance based design utilising fire safety engineering (FSE) is possible in many countries. At product level, either European test and classification methods or engineering methods are used to determine required classes or performance of materials, products and building elements.

Regulations based on prescribed solutions are often causing problems by categorising materials and products as non-combustible (at least A2 reaction to fire class) and combustible (not allowed at defined applications). Performance based regulations (or performance based options in regulations) are more flexible when being material independent.

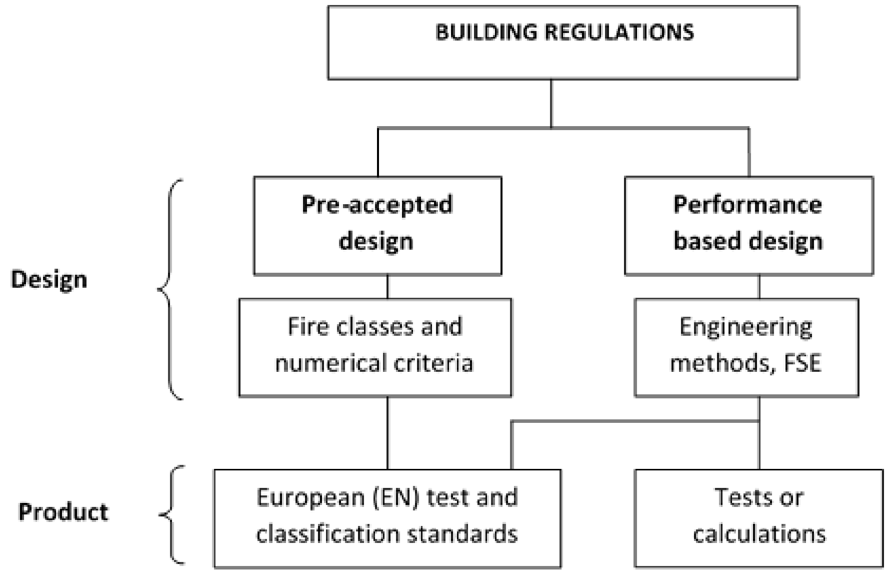

Figure 1. Presentation of regulatory tools concerning fire safety in buildings.

Main objectives of *COST ACTION FP1404 WG3, Regulations and standards for fire safety of bio-based building materials*, are the following:

- Comparing regulatory approaches in different countries and identifying unsolved topics/obstacles to use of bio-based materials
- Based on performance/risk based approach development of performance criteria for harmonisation of technical fire safety requirements
- Reducing burden of unnecessary fire testing.

Collaboration between FP1303 and FP1404 is foreseen very valuable because FP1303 can provide basic material data on a large variety of bio-based building materials. On the other hand, fire performance is one of the basic requirements of building products and is necessary to know to enter to the market after satisfying requirements. FP1404 can provide not only information on testing methods and national requirements but also advanced knowledge on fire safety engineering methods to help new materials and products getting acceptance. The overall aim is to ensure safety of people and property in use and also in construction phase.

Challenges of research and development of bio-based materials are to reach the best reaction to fire performance classes (low combustibility and smoke generation) or to incorporate these materials within building elements (*e.g*. insulation materials). Also toxicity aspects may be relevant in the future.

Acknowledgments:

FP 1404 partners and European fire standardisation colleagues are thanked on their contribution to the technical background of fire performance assessment of building products.

The Morphological Characterization and Thermal Analysis of Cellulose Biocomposites with Nanoboron Nitride

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Keywords: Biocomposite, cellulose, nanoboron nitride

Biocomposites based on cellulose fibers (CF) obtained different renewable plants are an important sustainable raw material for many industries. Environmental concerns also have increased the interest in materials from renewable resources (Shchipunov 2012, Mittal 2011). Biocomposites which is a novel class of materials composing of bio-polymers and bio-fillers have the improved physical, mechanical, and other properties when compared with properties of polymers (Rhim *et al*. 2007, Kumar *et al*. 2010). DTG–TGA and SEM methods were used to determine the morphological structure and thermal stability of the biocomposites. The biocomposite sheets were prepared by the casting method with different filler loading rates (0%, 2% and 6%) of nanoboron nitride (NBN). Mixing between NBN and cellulose was done by using the mechanical homogeniser. The results showed that NBN has an improved effect on thermal stability of the biocomposites as depending on loading rates of fillers (Table 1; Fig. 1).

Table 1: The summary of thermal analysis of biocomposites.

Samples	$T_{10\%}$	$T_{50\%}$	DTG_{max}	Weight loss (%)
CF	75	341	350	87
CF with 2%NBN	254	378	345	64
CF with 6%NBN	322	Above 725	347	27

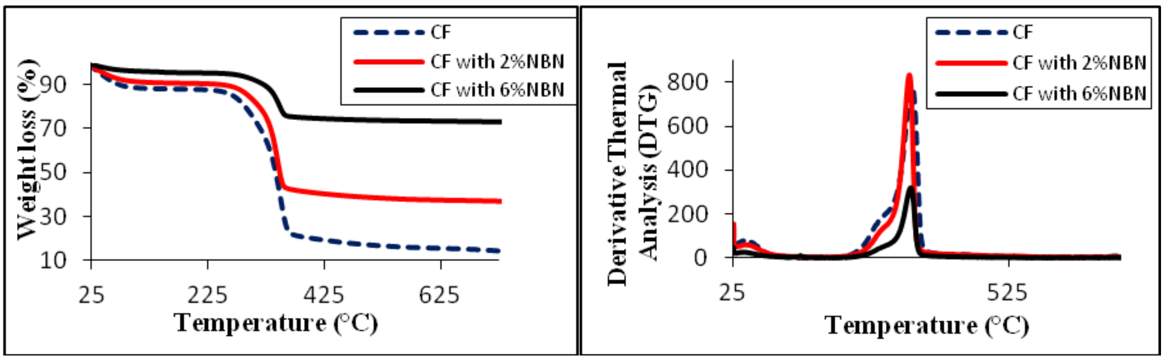

Figure 1: Weight loss (left) derivative thermal analysis of weight loss (right) of the biocomposites

The morphological studies revealed that NBN filled blanks of the cellulose and they enhanced surface smoothness of cellulose films. The homogenous distribution of fillers due to good interaction between CF and NBN appears to be the cause to improved properties in the biocomposites (Fig 2, 3).

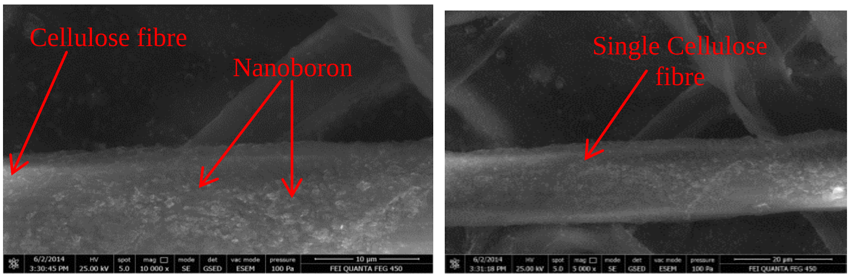

Figure 2: The interaction between cellulose fibre and nanoboron nitride

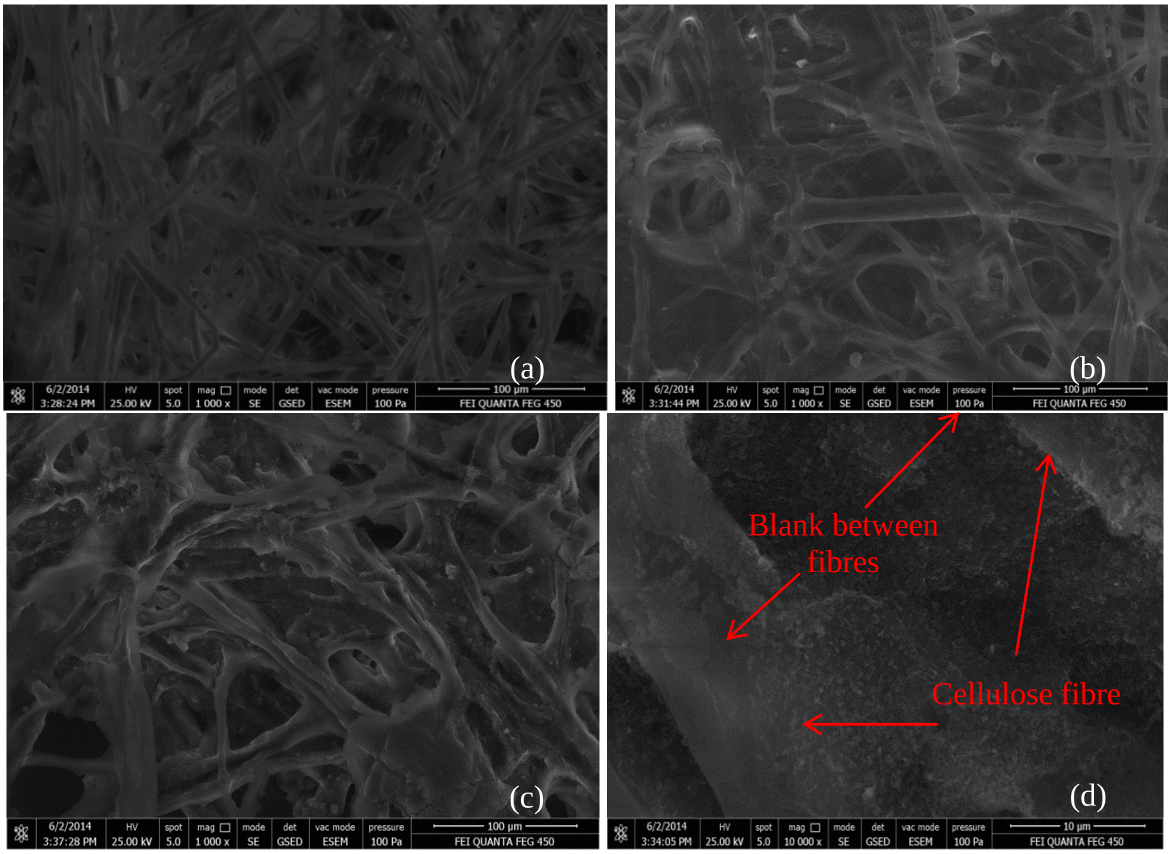

Figure 3: Biocomposites with different loading rates of nanoboron nitride (a): Cellulose fibre (b): with 2% of nanoboron nitride (c) with 6% of nanoboron nitride (d) the filling effect of nanofillers between fibres.

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Mechanical performances of solid wood used in buildings: effects of moisture interaction and natural drying

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Keywords: Green wood, crack, moisture interaction, drying strains, performance testing

This work complements the study presented in the first conference of COST Action FP1303 related to the behaviour of notched beam used in building in Europe (Moutou Pitti *et al.* 2014). This work is focused on the behaviour of solid wood element due to natural drying process. We propose a 3D measurement method by image analysis of strains induced by natural drying of a green wood slice. The drying process undergoes deformations leading cracking (Moutou Pitti *et al*. 2008).

Material and methods

The thickness and the diameter of the slice (Silver fir of Massif Central in France or *Abies alba* Mill.) are respectively 2 and 25 cm. To measure the mass loss during drying phase, a precise electronic scale is connected to a computer with a data acquisition system. 2 cameras are positioned on the same support so as to have a 3D view of the slice, Figure 1(a). After placing targets their coordinates x, y, z are calculated with an accuracy of 1/20000 of the dimension the measurement field, Figure 1(b). Variations of these coordinates are calculated to obtain the strains in a cylindrical coordinate system. The ultimate cracking occurs on the 5th day through an acquisition of one image/min to record the start of cracking.

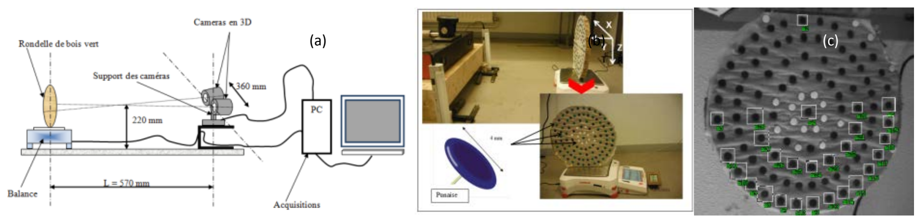

Figure 1: (a) Schematic of experimental device. (b) Real experimental device. (c) Numeration of targets

The tacks (10 mm diameter) are placed on the slice concentrically, Figure 1(b). To improve the contrast between the target and the support, a pre-drilled layer is installed; pre-drilling avoids creating a waterproof screen and weakens the layer for possible cracking. To follow the deformations, a 3D camera is placed in front of the slice (Figure 1(b) and (c)). The camera is positioned vertically on a scale that measures the mass loss every 30 seconds. At the beginning of the test, the balance has an initial mass of 494.97 g.

Results and discussion

After four days of test (Figure 2(a)), there is a significant loss of mass of the specimen with more appearance of several cracks on its periphery. These cracks continue to evolve until one of them continues to spread at a time when others begin to close. On the fifth day, the crack reaches the centre of the specimen, causing at the same time closing the other cracks, Figure 2(a). The most important radial strains are also located near the crack, Figure 2(b).

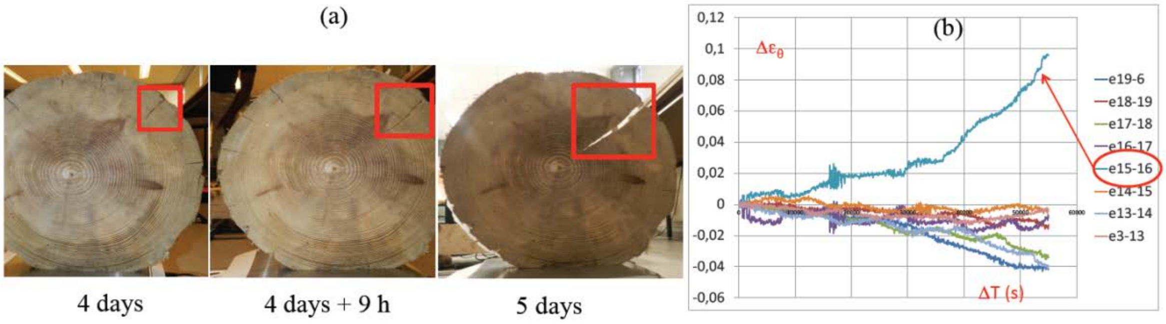

Figure 2: (a) Crack appears vs. time. (b) Evolution of radial strains vs. time

Conclusions

The method used to characterise the strains in wood during its natural drying, has proved effective. The 3D measurement has to ensure that the slice during drying has not undergone rotations that might taint the calculations of plane deformations. In coming works, the study of the effect of the variability of the mechanical properties of wood on the drying kinetics; the study of the effect of the drying kinetics in variable climate and improving accuracy of the experiment, including the optimisation of measurements of target location will be investigated.

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Acknowledgments

The authors thank Pascal Institute for funding the Master who conducted these tests, Joel Garmy of Auvergne-Promobois Association, and ANR through CLIMBOIS ANR-13-JS09-0003-01 project.

Development of novel bio based panels for use in internal door manufacture

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Keywords: natural fibre-plastic composites, door manufacture, computer modelling

There is a growing need for doors with enhanced performance in terms of security, acoustics and fire performance in public buildings such as schools and hospitals. In order to achieve this, it is necessary to develop alternatives to solid timber door systems. The Silentwood project, funded through the EU Framework 7 programme aims to develop and validate a novel, price-competitive, certifiable exterior wooden-based door with enhanced acoustic performance to attend the growing demand and comply with increasingly stringent building legislations for residential, educational and sanitary premises.

The aim of Silentwood is to allow the target SME associates (members of participating SME-AGs) to comply with existing building regulations at European level while increasing their long-term competitive margin and, at the same time, to open a new door for panel manufacturers to new market opportunities that can help them face their current critical situation. This project has also the goal of contributing to the foundation of a common European regulation on building acoustics. Among key considerations within this work are:

- Sound reduction index of 45 dB
- Weight limit of 60 kg per door
- Thickness 45 mm maximum
- Incorporate biobased materials
- Be cost competitive, preferably between 200-300 €

Among the fibres considered were wood fibres (both softwood and hardwood), hemp, flax and sheep's wool. The thermal properties from natural fibres (Sutton and Black 2011) demonstrate their beneficial use in products such as doors and other building products (Table 1).

This presentation will describe the development of natural fibre-plastic composite systems for use in conjunction with insulation materials such as natural fibre and inorganic fillers. Work will describe the two modes of assessment undertaken, whereby results from computer simulation models will be compared against actual laboratory based results. Figure 1 shows an example of the output from a modelled scenario of wood with epoxy resin, which could be used in predicting the strength and acoustic performance of the panels.

Table 1: Thermal performance of fibres

Type of material	Typical thermal conductivity (W/m/K)
Natural organic materials	
Wood fibre	0.038 – 0.050
Paper (cellulose)	0.035 – 0.040
Hemp	0.038 – 0.040
Wool	0.038 – 0.040
Flax	0.038 – 0.040
Cork	0.038 – 0.070
Inorganic materials	
Mineral (rock) fibre	0.032 – 0.044
Glass fibre	0.038 – 0.041
Synthetic materials	
Extruded polystyrene	0.033 – 0.035
Expanded polystyrene	0.037 – 0.038
Polyurethane / polyisocyanurate	0.023 – 0.026

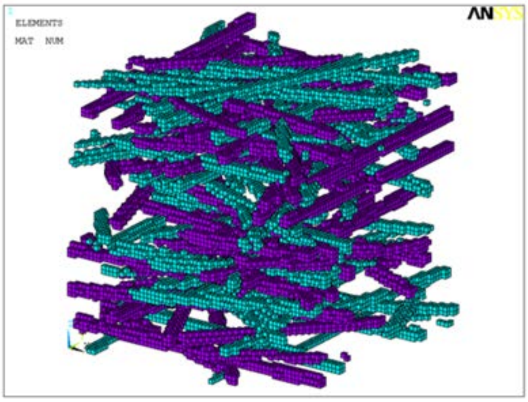

Figure 1: An example of modelled unit of wood tracheids and epoxy resin

Results will focus on the manufacture and testing of composite materials, comparison to modelled results and results from prototype doors produced in the project.

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Acknowledgments:

The authors would like to thank the involvement, interest and expertise of all project partners who have helped contribute to the development and delivery of this project and to the EU Seventh Framework Programme for their funding of this work, under grant agreement number 234639-2.

Lignocellulosic reinforcement of pine beams

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Keywords: Bamboo**;** LLBC plate; Reinforcement; Knots

This work aims at determination the possibilities of application lignocellulosic material as local reinforcement of pine beams. Test beams were reinforced with layered laminate bamboo composite (LLBC) plates (Fig. 1). Table 1 presents properties of LLBC used.

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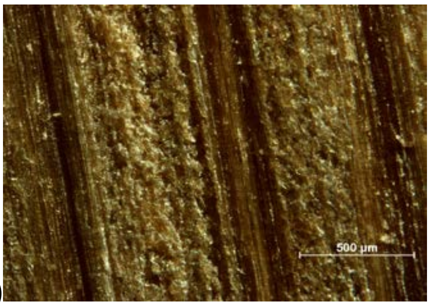
b) 

Figure 1: (a) LLBC plate and (b) its optical micrograph

Table 1: Properties of LLBC [Kozakiewicz 2010; Verma *et. al* 2012]

Property	LLBC
Density (kg/m^3)	900
Young's modulus (GPa)	9.5
Tensile strength (MPa)	110

Described local reinforcement technique consists in strengthening by gluing the LLBC plate to the pine beam with an epoxy glue. The reinforcement is placed in the tensile zone of bent beam. Gluing characteristics were determined with respect to surface wettability and surface energy for all materials used (pine wood and LLBC plate). Testing was performed with a Phoenix 300 goniometer. The results of are presented in figure 2.

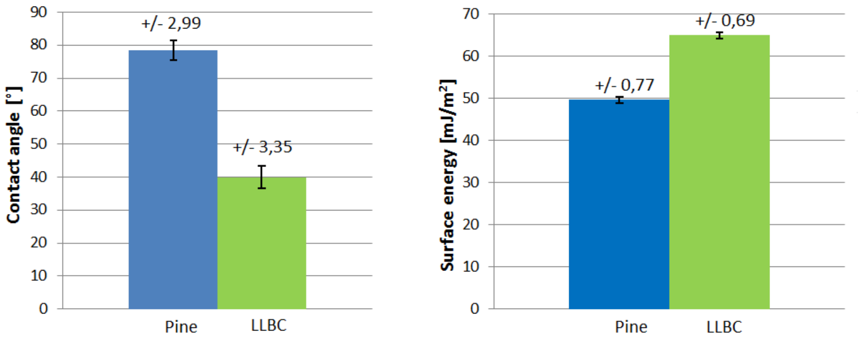


Figure 2: Contact angle and surface energy values for tested materials. Data provided as the mean ±SD

The effective length of local reinforcement reached 5% of the entire beam length [Burawska *et al.* 2011]. Beams were tested to determine static bending strength in accordance with the EN-408 (2012) standard (Table 2). Test materials were divided into three groups: A - pine beam, weakened with an 18-mm hole; B – weakened pine beam, locally reinforced by 1.2-mm LLBC plate; and C - weakened pine beam, locally reinforced by 4.2-mm LLBC plate.

Table 2: MOE and MOR values obtained during testing

	MOE (N/mm^2)	**St. dev (N/mm^2)**	**MOR (N/mm^2)**	**St. dev (N/mm^2)**
A group	15442.4	2144.7	38.25	11.25
B group	23059.2	7045.7	65.52	13.89
C group	20664.1	5370.5	76.27	18.14

Based on performed tests it may be concluded:

- The LLBC, because of its rough surface, low contact angle and high surface energy, is perfect for gluing. The bond and wood-bond-LLBC contact area are not prone to cracking.
- The LLBC, as a natural and renewable material, is an interesting alternative to synthetic, highly processed materials.
- Application of LLBC plate as a reinforcement material significantly increase the MOR and MOE of timber.

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Properties of Parquet Finishing by Means of Oils and Waxes

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Keywords: antique wooden parquet / traditional surface finishing techniques / wood durability / resistance to abrasion / resistance to scratches / colour and gloss changes

Aim of study. Traditional techniques and materials constitute an important element of the cultural heritage of Europe. In antique buildings, until the 1st half of the 20th century were used: varnishing (repeated soaking with hot varnish until full saturation of wood surface) and waxing. These are traditional techniques that make use of natural substances and ecological technologies. Applied when hot, the substances penetrate deeply into the wood's structure, without creating a layer on its surface that could be, potentially, quickly damaged, losing its decorative value. Moreover, wax and varnish leave the effect of natural wood structure, with a beautifully highlighted pattern. Studies of the resistance properties related with the application of traditional finishing materials show that it is possible to use them nowadays, as their properties are similar to the contemporary methods.

Materials. We investigated the properties of finishes using antique (Rozanska *et al*. 2011) and contemporary wood samples of different species: oak -*Quercus* sp, elm –*Ulmus* sp, ash- *Fraximus excelsior* L and pine- *Pinus sylvestris* L. We used natural bee wax obtained from a bee yard in honeycombs, varnish (linseed) and contemporary synthetic parquet oil (commonly used due to its low price) (Rozanska *et al.* 2012, Rozanska *et al*. 2013).

Methods. The properties of finishes were evaluated by microscopic and macroscopic investigations through: visual inspection, tests of wood colour and gloss, as well as tests of the hardness, resistance to abrasion and resistance to scratches both before and after covering the surface of chosen wood species samples with finishes. Brinell hardness tests were conducted according to PN-EN ISO 5470-1:2001 standard. Abrasion resistance tests were conducted with the use of a Taber device in accordance to the PN-EN ISO 5470-1:2001 standard, consisting in the calculation of the sample's mass loss after 100 revolutions. Resistance to scratches tests were conducted with the use of a Taber device on the basis of the PN-EN 438-2:2005 standard. The change in gloss and colour was determined in accordance with the PN-EN ISO 7724-1:2003, PN-EN ISO 7724-2:2003, PN-EN ISO 4892-1:2001 and PN-EN ISO 4892-2:2006 standards. The total colour difference ΔE^*_{ab} was calculated on the basis of the PN-ISO 7724-3:2003 standard. Gloss was measured in accordance to the PN-EN ISO 2813 standard.

Results. The wood soaked with hot varnish changed colour – it darkened and the pattern got intensely saturated. Moreover, stains and discolourations became more visible. Similarly, the finishing oil that is available nowadays also caused the wood colour to darken and made its pattern intensely saturated, just as in the case of varnish. Wax refills the mechanical damages of its surface: gaps, indentations and cracks. It does not cause a significant colour change of the wood, it only makes it intense. It does not increase the visibility of stains and wood discolourations. Both cracks and indentations (the most frequent damages of wooden surfaces) become less visible and do not accelerate wood degradation. In spite of their presence, the surface of wood is adequately protected against humidity and dirt.

Covering with finishes cause changes in gloss (specially increased gloss in case of wax).

The comparison of Brinell hardness test results of samples without finish and samples covered with varnish, wax and contemporary synthetic oil, shows that the kind of surface finish does not have a major influence on the change in hardness in case of antique wood. The hardness results are comparable due to the standard deviation.

The scratch width tested on the different samples with and without finish substances shows that surface finishing with wax or varnish practically does not change the resistance to scratches. The scratch width in case of wood covered with wax, varnish and synthetic oil is also comparable.

The abrasion resistance grows significantly after samples are covered with wax, varnish or synthetic oil. The biggest increase of average abrasion resistance occurred when the wood was covered with wax, and then synthetic oil and varnish correspondingly. It is worth mentioning that the standard deviation has much smaller values in case of samples covered with finish coatings.

Conclusion. The test results reveal differences in aesthetic properties and similarities in resistance properties of surfaces finished with wax and varnish. Therefore, the most important criterion of finishing substance selection is the aesthetic feature. Wax and varnish applied at high temperature are not film-forming, just as the contemporary parquet oil that is applied cold. The application of varnish causes more problems. Moreover, varnish also gives the worst results as far as parquet aesthetic features are concerned. The use of wax as surface finish intensifies the pattern of wood, does not result in too much colour darkening, increases the gloss and fills minor cavities in the wood. However, covering the surface with wax makes it more slippery. Moreover, surface covered with wax is prone to suffer visual defects, due to the fact that wax penetration into the wood is less deep. Wood surface with contemporary parquet oil finishing acquires similar aesthetic and resistance properties as in the case of varnish. Contemporary oil has a nice smell and it eliminates the unpleasant visual effect of greasy surface. However, just as varnish, it darkens the surface, highlights the stains, and does not fill the gaps, which may result in aesthetic defects. The basic technological problem related to the contemporary parquet oils is the fact that they should be applied several times (about 6 times with a minimum of 3-week intervals), while the effect of wax application is relatively fast.

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Different spectral techniques used to identify the state of wood degradation by soft rot fungi

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Keywords: CP/MAS ^{13}C-NMR spectroscopy, infrared spectroscopy, 2D COS, biodegradation

Wood samples of lime (*Tilia cordata* Mill.) were subjected to biodegradation with soft rot fungi (*Chaetomium globosum*) for different periods of time and up to 133 days. The weight loss of the studied samples was evaluated. Exposure time-dependent CP/MAS ^{13}C-NMR spectra of biodegraded wood, and IR spectra, combined with their second derivative analysis and 2D IR correlation analysis can provide detailed information on the modifications at a molecular level of the cell wall components induced by the fungus decay.

By solid state ^{13}C CP/MAS NMR spectroscopy, the relative content of carbohydrates (hemicelluloses and cellulose) in the wood samples was observed to decrease with increasing the biodegradation time. It was evidenced a simultaneous loss of both hemicelluloses and cellulose with small changes in lignin structure, manly loss of methoxyl groups and Cα-Cβ bonds cleavage and β-O-4 linkages (Popescu *et al*. 2011).

At the same time, by infrared spectroscopy a decrease of the bands intensities assigned to different vibrations of the groups belonging to carbohydrates and the increase of the bands assigned to C-O and C=O groups, indicating the formation of oxidised structures was evidenced. As in the other spectral technique used, the decrease of the bands assigned to C-O in methoxyl groups indicated the modification of the lignin structure (Popescu *et al*. 2010).

2D IR correlation spectra provided the possibility to analyse and explore the order of the structural changes appearing during the biodegradation process.

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Analysis of small diameter pine logs distribution into the strength class

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Keywords: pine wood, strength class, building construction timber

Nowadays international timber markets experience strong competition and timber-exporting countries are protecting timber quality by evaluation and certification strength properties of local grown timber species. Timber properties and their dependence on various factors are quite extensively studied world-wide. The analyses on the distribution of coniferous timber to the strength classes are becoming more and more sophisticated. In large quantities the small diameter roundwood is produced from stands thinning. Currently, this material has small commercially market and it is mainly are using for particleboards, or as forest fuel, but it could be used as building material. In addition, it is very important to determinate the small diameter roundwood stiffness-strength characteristics and the correlations with the sawn timber strength and stiffness.

In our previous research it was estimated that 40 – 60 year old pine wood has a sufficiently high bending and compression strengths (Aleinikovas, 2007).

Integrated comparative non-destructive methodology was used for the analysis of 266 small diameter pine logs (top end diameter from 6 to 14 cm), focused on modulus of elasticity, strength and the distribution into strength class according the EN 338. The non-destructive tests were done using following device The Timber Grader MTG, used for measuring the timber strength and stiffness (Brookhuis Microelectronics BV, Holand). Log dynamic modulus of elasticity was calculated according the natural frequency, average wood density and moisture content of the log.

The obtained result show that only 32 percent of analysed pine logs are rejected (Fig 1). Thus, the rest amount of logs was in correspondence to the timber market minimal requirement of popular strength classes C18 and C24. Hereby, the timber logs already could be outlined as a building construction timber.

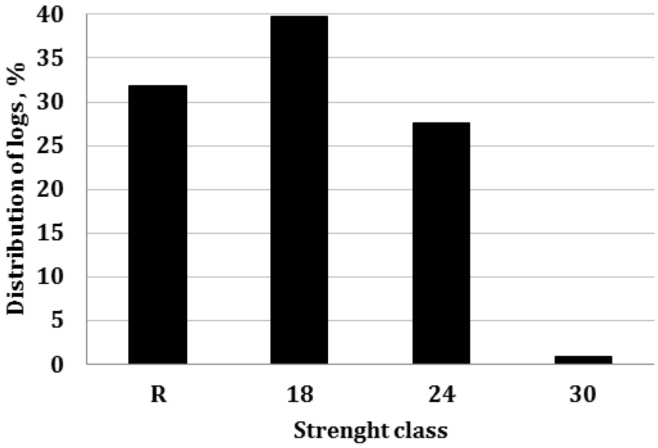

Figure. 1 Small diameter pine logs strength grading

The modeling on the reliant of the log dynamic modulus of elasticity was performed according to the main influencing parameters. Initially the relationship between log top-end diameter (Figure 2a) and logs density (Figure 2b) with the dynamic modulus of elasticity (MOE) was tested (Fig 2).

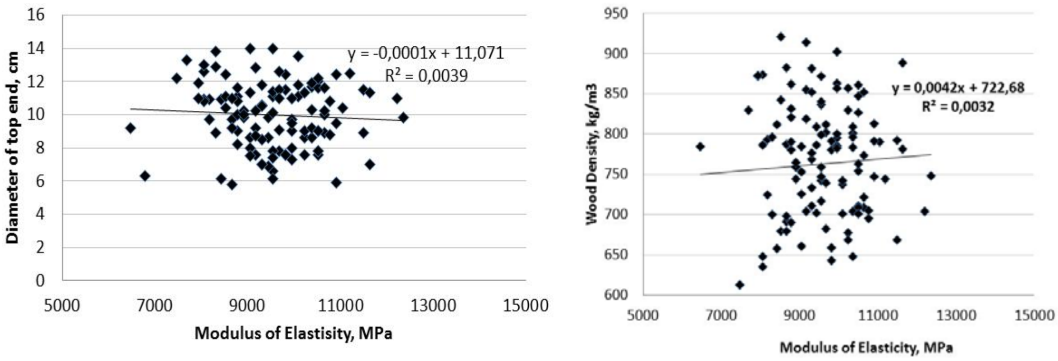

Figure 2 *Modulus of Elasticity depends on log topend diameter (a) and dry wood density (b)*

As our results shows, the modulus of elasticity was not depending on log diameter. The obtained results are not unusual or controversial. However, the DMOE of wet logs significantly correlated with the density. Nevertheless, the small diameter of this type of timber is limited factor for that to be used as the building constructions.

The effect of pMDI addition to PF resin on some OSB mechanical properties

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Keywords: OSB, pMDI, PF, mechanical properties.

Resins used in the manufacture of OSB Type 3 (load-bearing in humid conditions, acc. EN 300:2000) are isocyanates (pMDI), phenolic based resins (PF, MUPF) or UF resins with melamine addition (MUF). The most effective is pMDI but due to production costs it is not applied on a large scale outside Europe. A practical solution is a hybrid resins, pDMI/PF has been used for many years in wood based panels manufacturing (*e.g.* plywood for special applications) and it is protected by many patents (Zheng *at al*. 2004, Riedlingera and Frazier 2008). Nevertheless, the hybrid resins require further research and the addition of PF resin can significantly reduce costs, while maintaining good properties and meet requirements for panels load-bearing and resistance to humidity like the OSB/3. The aim of this work was to study the mechanical properties of OSB bonded with PF resin with addition of pMDI in the ratio 0, 10, 25, 50, 75 and 90%. The control board was bonded with pure PF resin (0% pMDI). Adhesives properties are presented in Table 1.

Table 1. Properties of resins

Property	Unit	Numerical value	
		PF	pMDI
Dry mass	%	45.8	100
Viscosity	mPas	635	215
Density	g/cm^3	1,208	-
pH	%	12,47	-
Miscibility with water	mg/kg	0,8	
NCO content		-	30,9
Chlorine hydrolytic		-	96

The tested properties were elastic modulus (E) and bending strength (f) acc. EN 310:1994. From the glued strands ware formed 3-layers OSB boards having fixed parameters: thickness (t) of 15 mm and a density of 590 kg/m^3. Pressing was done in 345 s at the temperature 200^{o}C. The tested properties of manufactured boards are presented in Table 2. All boards had similar mean density. This effect was achieved by using strands for outer layers with low content of fines. The OSB bonded with PF resin was characterised by good mechanical properties, higher than requirements for OSB/3 and slightly lower than OSB/4, according to standard. The board bonded with 10% addition of pMDI met entirely requirements also for OSB/4. Generally, with the increase of the amount of pMDI in the mixture of adhesives, the mechanical properties of OSB were better.

Table 2. OSB properties depending on the percent amount of pMDI in the adhesive mixture PF/pMDI

Property	Unit	Numerical value						
		0*	10	25	50	75	90	100
ρ	kg/m^3	613(6.3**)	603(3.3)	600(5.7)	604(5.8)	614(4.4)	608(4.5)	588(4.6)
f_m II	N/mm^2	27.5(7.9)	30.0(12.0)	31.0(11.3)	31.0(14.4)	33.1(4.6)	35.6(11.8)	35.7(9.7)
$f_m \perp$	N/mm^2	17.6(9.34	20.2(9.2)	20.8(7.2)	21.6(11.7)	21.8(6.5)	22.1(8.3)	22.3(5.7)
E_m II	N/mm^2	4670(5.2)	5180(5.7)	5370(10.1)	5320(8.3)	5610(3.9)	6150(9.2)	6190(4.9)
$E_m \perp$	N/mm^2	2120(7.1)	2400(8.4)	2580(10.0)	2600(5.9)	2630(5.4)	2560(8.0)	2670(5.3)

* - content of pMDI (%), ** - the variation coefficient

The analysis of the obtained results using the HSD Tukey test (Table 3) indicated that in case of bending strength specified for the axis larger, significant changes in the properties were observed at 75% content of pMDI. Increasing the content of pDMI from 90 to 100% did not cause increase of mechanical properties compering to 75% pMDI addition, not include elastic modulus.

Table 3. Results of Tukey test- the influence of pMDI addition in the adhesive mixture PF/pMDI on OSB properties

Property	ANOVA(6,77)	Error MS	HSD Tukey test					
			0→10	0→25	0→50	0→75	75→90	75→100
f_m II	p=0,0000	11.681	0.541527	0.168099	0.165587	0.002658	0.529725	0.487954
$f_m \perp$	p=0,0000	3.1785	0.008225	0.000851	0.000129	0.000127	0.998657	0.990381
E_m II	p=0,0000	1565E2	0.039259	0.001019	0.003065	0.000126	0.018333	0.009093
$E_m \perp$	p=0,0000	33565	0.007330	0.000125	0.000124	0.000124	0.964907	0.998613

The study shows that the small addition of pMDI (10%) to the PF resin improved the mechanical properties of OSB so that they met the requirements for boards OSB/4. It was also found that the replacement of 25% of pMDI resin by PF (75% pMDI / 25% PF) did not significantly decrease the mechanical properties of boards, and it should significantly reduce the cost of the adhesive mixture for the industrial use.

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Rapid determination of IPBC in indoor air using gas chromatography-mass spectrometry / headspaces solid-phase microextraction (HS-SPME)

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Keywords: solid phase micro-extraction (SPME), IPBC, building materials

Iodopropynyl butylcarbamate (IPBC) is found in a wide variety of industrial and consumer products including building materials, paints, coatings, wood preservatives, metal working fluids, cooling water, household products and cosmetics (Badreshia, Marks 2002). IPBC has been used as an industrial fungicide since 1970s. According to "Word Guide to Industrial Biocides" IPBC is reported as the most commonly used industrial antifungal agent.

GC-MS in combination with headspaces solid-phase microextraction (HS- SPME) has been applied successfully to a wide range of analytical applications involving indoor air (Pawliszyn 1997, 1999 Scheppers - Wercinski 1999).

The objective was to determine IPBC emission from preservative - treated timber using the technique of solid-phase microextraction (SPME).

Chromatographic profile of volatile organic compounds (VOC) obtained by the HS-SPME technique, using SPME fibre for extraction of samples. In this study 34 individual VOCs were identified in the collected compounds from wood samples on the basis of mass spectra in this IPBC. The most abundant individual compounds in the emission of wood samples were: α-pinene, camphene, β-longipinene. According to the earlier Scots pine study, the terpenes were the main compound group in the VOC emission (Raisanen *et al*., 2009; Manninen *et al*., 2002; Risholm-Sundman *et al*., 1998). Selected ion monitoring (SIM) was applied to determine IPBC due to a lot of VOC from indoor air. In SIM mode, a single peak was obtained at retention time of 21 min. The mass spectrum of this peak contained a molecular ion at m/z 281 and other key fragments m/z 238, 165, 127. The analysis of the spectrum of this compound indicates that it was IPBC

Owing to the application of the SPME technique, it was possible to identify IPBC on indoor air. Solid phase microextraction (SPME) is a modern technique to isolate volatile compounds in this IPBC and it can be an alternative to traditional methods.

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Biological performance of wood-plastic composites containing zinc borate. Part 1: Laboratory test results

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Keywords: Polymer-matrix composites, decay, termite performance, zinc borate.

Wood-plastic composites (WPC) or natural fibre reinforced thermoplastic composites represent a new class of hybrid material gaining great market potential around the world. After Morris and Cooper (1998) reported brown rot and white rot fungi growing on wood-plastic composites in service in Florida, a great deal of research regarding biological resistance of these composites has been conducted. Any WPC formulation without wood preservative chemical only relies on encapsulation properties of the plastic matrix against biological agents. The thermoplastic matrix is expected to act as a barrier to exclude moisture and fungal activity. Six different formulations of wood-plastic composites (WPC) fabricated from wood and polypropylene (PP) were tested in the laboratory against decay and termite activity. Variables examined included comparisons of untreated and zinc borate (ZnB) incorporated formulations, wood content ratio, wood particle size and increased surface area *via* surface grooves (channels) to promote moisture infusion. The WPC were produced from multi-component formulations consisting of wood, thermoplastic matrix, inorganics, process additives and pigments by Misawa Homes Co. Ltd. Japan. Formulation details of WPCs tested are given in Table 1.

Table 1: Details of WPC formulations tested.

WPC group	Wood content [%]	Particle size [mesh]	Wood [g]	PP [g]	Zinc borate [g]	Total weight [g]
1	50	60	30.69	25.12	-	60
2	50	30	30.69	25.12	-	60
3	70	60	41.86	13.95	-	60
4	70	30	41.86	13.95	-	60
5	70	60	41.26	13.95	0.6	60
6	70	30	41.26	13.95	0.6	60

Wood flour 60 and 30 mesh was obtained commercially. The thermoplastic resin was commercial polypropylene (PP) [a homo-polymer (E-200GP)] with a melting point of 160 ºC and a melt flow rate (MFR) of 2.0 g 10 min^{-1}. Fine powdered zinc borate (ZnB, US Borax, Valancia, CA.) was added at 1 % (w/w) into the formulations five and six during the manufacturing process. Laboratory decay and termite tests were conducted according to Japanese Industrial Standard (2004) with the following exceptions: 1) WPCs instead of solid wood specimens were evaluated; 2) the specimen size was 20 (L) x 20 (W) x 4 (T) mm instead of 20 (L) x 20 (W) x 10 (T) mm; 3) post-decay moisture contents of WPCs were measured. Sugi (*Cryptomeria japonica* (L.f.) D. Don) sapwood specimens were also prepared according to the JIS size as reference material. All specimens were oven dried at 60±2 ºC for 48 hours and their initial weights were recorded before subsequent decay and termite tests. The decay test specimens were sterilized with gaseous ethylene oxide under vacuum for 12 hours. Three specimens were exposed to a monoculture of either *Trametes versicolor* (L.:Fr.) Pilat [a white-rot fungus; Forestry and Forest Products Research Institute of Japan (FFPRI) 1030] or *Fomitopsis palustris* (Berk. et Curt.) Gilb. & Ryv. (a brown-rot fungus, FFPRI 0507) in a glass jar at 26 ±2 °C for 12 weeks in the dark. *Coptotermes formosanus* Shiraki was used in termite tests. Wood decay fungi and Formosan subterranean termite activity in laboratory tests resulted in different mass losses, post-decay moisture contents and field test ratings depending on their wood and ZnB content . The results show that as wood content increased, mass losses also increased. Addition of ZnB at 1 % (w/w) retention level significantly decreased mass losses of wood-plastic composite when exposed to laboratory decay and termite tests. The effects of surface grooves and wood particle size were less important, compared to wood particle content.

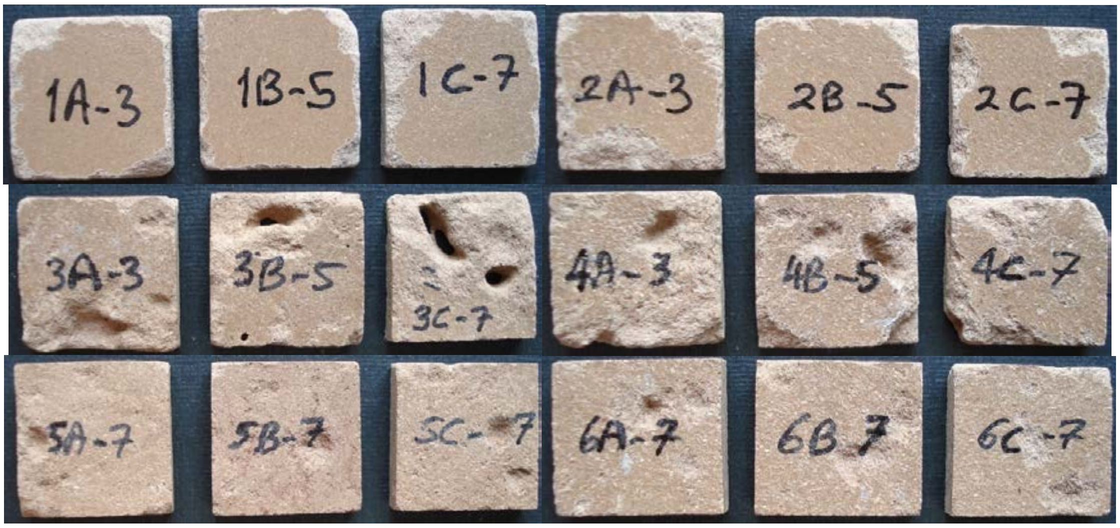

Figure 1: Typical damage modes of laboratory termite activity on representative specimens from all WPC formulations tested.

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Water vapour sorption properties of wood cell wall polymer constituents

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Keywords: Lignin, hemicelluloses, hydrolysis, dynamic, DVS

Abstract

Lignin, cellulose and hemicelluloses have main roles on swelling and shrinkage of wood products. Interaction of these components with moisture has an important effect on market-friendly when the wood is subjected to the outside utilisations. The water molecules are generally thought to be absorbed to a hydrophilic surface (Brunauer *et al.*, 1938) or by adsorption sites (Frank and Wen, 1957). The numerous hydroxyl (OH) groups associated with the cell wall macromolecules are usually assumed as an adsorption sites in the lignocellulosic materials (Hill *et al.*, 2010). Those hydroxyl groups capable to form hydrogen bonds with water molecules are termed sorption sites (Simpson, 1980) along with other polar chemical groups attracting water (Berthold *et al.*, 1996). The most sorption sites are found in the hemicelluloses followed by cellulose and lignin (Engelund *et al.*, 2013; Rautkari *et al.*, 2013). In the heterogeneous structure of wood, sorption and desorption are occurred in different stages and it calls hysteresis. Hysteresis is a characteristic result from a moisture/temperature/time-dependent, slow, non-equilibrium, swelling-related conformational change, which is facilitated by increasing free volume and mobility in a polymer that is being plasticised during sorption that usually progresses through the stage of water clustering (Reina *et al*. 2001).

The main objective of present study was to establish the effect of cell wall component on the water vapour sorption properties of wood veneers. The water adsorption and desorption mechanism of treated and untreated veneers were determined using a dynamic vapour sorption (DVS) apparatus. Cell wall polymers of Scots pine showed a different behaviour in the face of moisture in terms of adsorption, desorption and hysteresis. The results indicated that with increasing the ambient pressure (higher than 60% relative humidity), hemicelluloses exhibited considerably high moisture adsorption/desorption and hysteresis than other wood component.

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PLA reinforced with modified cellulose nanocrystals

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Keywords: cellulose nanocrystals, PLA. silanes, fatty acids

This work was aimed to evaluate the performance of two different surface modifications on cellulose nanocrystals. different composites were elaborated using poly(lactic acid) as matrix varying fiber concentrations and using cellulose nanocrystals of diverse surface modification (3-Aminopropyl Triethoxysilane silanised cellulose nanofibres and Dodecanoyl Chloride esterified cellulose nanocrystals) . Composites were prepared using a Haake Minilab twin-screw extruder at 160 °C during 15 min. Bulk filler was added dry and mixed with PLA with a share of 0.5, 1.0 and 2.0 percent (Table 1). Composites were tested with stress-strain standard methods showing better mechanical properties when surface modifications were performed and the amount of filler was 0.5 wt% reaching an increase in strain of more than 20% (Freire *et al*. 2006).

Tensile tests of the composites were performed using MTS Insight 10 equipment provided with pneumatic clamps and 250 N loading cell, with a speed of 5 mm/min. Samples were prepared 60 mm long, with an average width of 5 mm and thickness of 0.7-0.9 mm. The set distance between the clamps was 20 mm. Mechanical test results were performed for the different composites, the values quoted are the average of ten measurements (Table 2). The addition of anisotropic material to the polymeric matrix influences the performance in uniaxial stress. It can be observed a considerable decrease on the mechanical properties when adding cellulose without any surface modification in composites reinforced with bleached pulp, cellulose nanofibres and cellulose nanocrystals, in which ultimate tensile strength (UTS) presents a decrease; this is accentuated as the percent of filler is increased, reaching a drop of approximately 25% when the filler reaches 2% of the composite. In general, the behavior of composites under uniaxial stress is similar to the obtained in previous publications, with an increase in the UTS and a decrease in the strain at fracture when cellulosic fillers are added (Kowalczyk *et al.* 2011); when the share of the filler inside the composite is increased, the anisotropy characteristic to organic fillers in polymeric matrices, gets a major role in the response of the composite to uniaxial stress, generating more dislocations inside the composite. Furthermore, higher amount of filler material can generate agglomerations that result in a deterioration of tensile stress transfer between matrix and filler, generating a more brittle structure (Zhang *et al*. 2008).

Table 1: Abbreviations used for the different reinforces used for the composites.

Bleached pulp	**BP**	**Cellulose nanocrystals**	**NC**
Cellulose nanofibers	NF	Cellulose nanocrystals + fatty acid	DC
Cellulose nanofibers + silane	NS		

Table 2: Mechanical properties of the different composites

	σ_{max} [MPa]			**ε [%]**			***E* [MPa]**		
PLA	45.29	±	1.04	11.18	±	0.98	755.72	±	82.08
BP 0.5	40.82	±	5.97	8.82	±	0.27	755.80	±	56.42
BP 1.0	18.76	±	2.68	7.70	±	0.49	887.08	±	72.33
BP 2.0	30.68	±	0.86	6.25	±	0.33	793.66	±	15.00
NF0.5	19.72	±	4.28	9.47	±	1.54	631.14	±	53.02
NF1.0	36.14	±	1.01	8.02	±	0.40	782.83	±	74.32
NF 2.0	35.10	±	1.05	7.66	±	0.18	762.22	±	37.72
NS 0.5	43.33	±	1.69	13.98	±	0.21	485.74	±	47.09
NS 1.0	38.63	±	3.51	10.55	±	0.75	838.81	±	109.45
NS 2.0	34.10	±	2.79	7.57	±	0.49	951.32	±	66.10
NW 0.5	36.58	±	0.91	8.62	±	0.52	842.76	±	26.09
NW 1.0	41.79	±	3.18	8.14	±	0.41	797.11	±	64.98
NW 2.0	3.18	±	0.64	0.41	±	0.91	1584.50	±	184.58
FA 0.5	43.48	±	2.38	13.23	±	2.78	796.23	±	190.56
FA 1.0	42.19	±	1.24	10.12	±	0.80	793.81	±	85.24
FA 2.0	36.88	±	1.39	9.26	±	0.92	817.76	±	74.80

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Reliability-Based Design Optimisation of timber trusses subjected to decay and climate variations

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Keywords: timber, optimisation, reliability, partial safety factors, degradation

The mechanical properties of timber structures over time are affected by a combination of loading, moisture content, temperature, biological activity, etc. This paper focuses on the optimal design of timber trusses subjected to decay. Since the deterioration processes and the structural behaviour 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 and Ritschkoff, 1991; Viitanen, 1996), Viitanen *et al.*, (2010) developed a model for the decay growth of brown rot in pine sapwood under variant climate conditions.

Structural optimisation is widely used for effective cost reduction of civil engineering structure. The deterministic optimisation procedure is successfully applied for designing concrete and steel structures (Kravanja *et al.*, 2013; Tomás and Martí, 2010). Recently, several works have used the Deterministic Design Optimisation (DDO) approach to design timber trusses (Šilih *et al.*, 2005) or to find the best design of finger-joint under bending test (Tran *et al.*, 2014). The DDO procedure is based on minimising an objective function as the structural volume or cost subjected to geometric, stress and deflection constraints. These design conditions are considered in accordance with Eurocode 5 in order to satisfy the requirements of both the ultimate and the serviceability limit states. In fact, the real benefit of the Deterministic Design Optimisation is cost reduction and effective use of structural capacity. The partial safety factors introduced in the deterministic design are assumed to take account for uncertainties related to timber material, structural dimension and loading. During the DDO Procedure these safety factors are applied in the design constraints to ensure the safety margin.

However, the design of timber structures involves several kinds of uncertainties related to wood properties, structural dimensions, and load fluctuations. In codes of practice as the EC5, these uncertainties are taken into account through the use of prescribed partial safety factors. These safety factors are calibrated for a large class of structures. Thus, the use of these partial safety factors in the deterministic design optimisation can lead to over or under designing structures. In fact, the long term durability of timber structures depends on the effect of moisture that in combination with propitious temperature conditions and exposure time may deteriorate the material resistance capacity. This exposition of the unprotected timber structures to persistent humidity exposure and high moisture content of wood can lead to biodeterioration 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.

These uncertainties inherent to material properties, material degradation, models and climate are considered throughout a time-dependent reliability based-design optimisation (TD-RBDO) approach (Aoues *et al*., 2009). The TD-RBDO aims to ensure a target reliability level during the operational life. This approach is applied to design optimisation of timber trusses subjected to French climates. The performance of the optimised solution is compared with a traditional cross-section designed according to the Eurocode 5 in terms of both costs and safety. The overall results indicate that an optimised solution reduces costs ensuring a target reliability level during the whole structural lifetime.

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Using isolates of decay fungi from field test samples for durability tests under laboratory conditions

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Keywords: basidiomycetes, mini-block test, monoculture, resistance test

In the frame of a short-term scientific mission (STSM) fungal isolates were sampled from field test specimens for identification and reproduction under laboratory conditions. Within the Swedish research program ‘WoodBuild’ comparative field and laboratory durability studies have been carried out by the Technical Research Institute of Sweden SP and Leibniz University Hannover. One objective was to improve test methods as well as evaluation systems in order to facilitate the use of (field) testing for service life prediction and to verify the suitability of different test methods for estimating the durability of wood under different exposure conditions. In addition to moisture performance and durability under field conditions, the resistance of all materials was assessed in the laboratory by conducting ‘mini-block’ tests (Bravery and Dickinson 1978). However, these tests were carried out using different standard test fungi, which are not necessarily the same species provoking decay or even failure of wood in the field and on structures in service. Therefore within this study isolation of decay causing fungi on field test samples in Borås, Sweden, and Hannover, Germany, were carried out. At both test sites approx. 40 different native, chemically and thermally modified as well as preservative treated wood-based materials were under test for a period of three years.

Isolates were taken from both, in and above ground field test specimens. The specimens were selected by macroscopic infestation characteristics like fruiting bodies, occurrence of mycelium and appearance of the wood surface. Borehole cuttings were taken by drilling a hole into the specimen to a depth of approx. 5 mm using a sterilized borer. Afterwards the adhering borehole cuttings were removed and sampled with a sterilized scalpel (Fig. 1). The fungi were then cultivated by putting the isolates on malt agar. After 16 days of incubation, the test fungi were selected by their growth velocity and optical appearance. We were able to incubate more than 30 isolates on malt agar. A screening mini-block test was started with untreated beech and Scots pine sapwood to evaluate the ability of the different fungi to degrade wood under laboratory conditions.

Figure 1: Sampling of isolates from in and above ground specimens exposed in the field.

Those fungi causing more than 3 % mass loss on either beech or Scots pine sapwood were selected for a comprehensive resistance test with a wider range of the materials investigated in the field. Furthermore the different species were identified with a DNA analysis using PCR, sequencing of the internal transcribed spacer of nuclear ribosomal DNA (nrDNA-ITS) and comparison with reference data from a gene bank database. Therefore fungal cultures were sent to IHD Dresden. The overall aim of this approach was to determine the ability of certain decay fungi to degrade wood and to identify fungal species which are responsible for decay in the field and might therefore be better indicators in lab tests.

In total 12 fungal isolates which caused mass loss > 3 % were used for testing 15 different wood-based materials.

In the main trial the isolated fungi *Trametes hirsuta, Gloeophyllum trabeum and Hypoxylon* sp. caused remarkably mass loss on maple, ash, spruce and Scots pine heartwood.

However, those fungi causing the most severe brown rot decay and which had been identified as *Leucogyrophana* sp. (most likely *L. pinastri*) were found to be difficult to colonise on malt agar. All isolates taken from field samples apparently infested by this basidiomycete suffered from little growth activity and infection by mould fungi occurred.

Various decay fungi as well as mould and other wood-inhabiting fungi were easily isolated from different field test samples and incubated on malt agar. The majority of species was identified at least on genus level. However, the decay activity of most isolates was less than expected when submitting them to a mini-block test with different wood-based materials. Further studies need to show to what extent results from laboratory decay tests with monocultures can be transferred to the field performance of wood.

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Testing of polysaccharide thermal insulations against fungi

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Keywords: pulp, sludge, thermal insulations, decay

Pulp and paper sludge (PPS) contain not captured pulp fibres from paper production, fillers from production of paper and cardboards, not overcooks and small parts of bark from pulp production, etc. Various types of PPS can be used for energy production, at composting, as additives for bricks, and potentially as thermal insulations. Bio-based, organic-synthesised and inorganic thermal insulations are used in roofs, ceilings and other parts of buildings.

Test methodology

This work discusses decay resistance of: (1) the commercial thermal Cellulose Fibre Insulation containing boric acid in a function of the biocide and fire retardant (Climatizer Plus– CFI); (2) and three potential thermal insulations from polysaccharide wastes (Pulp and paper sludge – PPS). Biological resistance test of all polysaccharide thermal insulations was performed in sterile laboratory conditions. Samples of fluffy insulations (m_0 = ca 3 g, *i.e*. in oven dry state with an accuracy of 0.001 g after sterilization at 103 ± 2 °C and cooling in desiccators) were sewn with polyethylene thread into perforated air-permeable and mycelium-permeable polyethylene bags. Bags with insulations were imposed into Petri dishes with agar-malt soil and fungal mycelia, and assessed for 16 weeks (in accordance with EN 113) against two brown-rot fungi occurring in such buildings which have a poor structural protection – the dry rot fungus (*Serpula lacrymans*) and the timber gill polypore (*Gloeohpyllum trabeum*) – Fig. 1. After completion of the test, the bags were opened, then the insulations spilled into glass containers, dried at 103 ± 2 °C, cooled in desiccators and weighed in oven dry state ($m_{0\text{-}F}$), and finally the mass losses Δm were determined.

$$\Delta m = [(m_0 - m_{0\text{-}F}) / m_0].100 \qquad (\%)$$

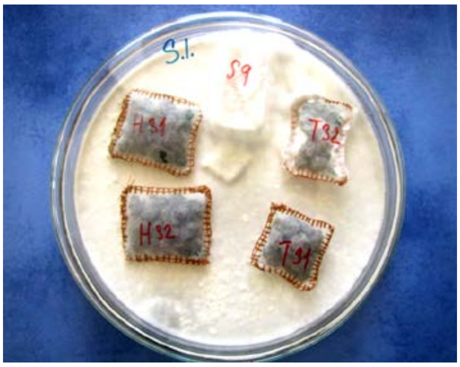

Figure 1: Mycological test of polysaccharide thermal insulations against *Serpula lacrymans (S.l.)*

Results

Polysaccharide thermal insulations from the pulp and paper sludge of 3 factories (PPS-1, PPS-2, PPS-3), each containing fractions from 1 to 10 mm, better resisted to decaying fungi as the commercial cellulose fibre insulation Climatizer Plus (CFI) – Tab. 1. This result can be explained by presence of trace amounts of some heavy metals with fungicidal efficiency in the PPS insulations, i.e. copper, zinc, but also others (Tab. 2). The PPS-1, with the highest amount of copper and zinc, had the highest resistance to decay (Tabs. 1 and 2). From fungi, the *S. lacrymans* – in comparison to the *G. trabeum* – had a higher sensitivity to heavy metals present in the PPS (Tab. 1).

Table 1: Mass losses (Δm) of polysaccharide thermal insulations (CFI, PPS) and Scots pine sapwood (Pine-solid) caused by the brown-rot fungi *S. lacrymans* and *G. trabeum*

Type of sample	**Δm [%]**	
	Serpula lacrymans	**Gloeophyllum trabeum**
CFI	14.90	19.07
PPS-1	2.36	6.94
PPS-2	3.41	7.85
PPS-3	4.48	9.05
Pine-solid	25.15	19.57

[a]Mean values of the mass losses are from five replicates (CFI, Pine-solid), or from fifteen replicates (PPS-1, PPS-2, PPS-3, when their each type was tested in three individual fractions /I. = 1 to 2.8 mm; II. = 2.81 to 5.6 mm; III. = 5.61 to 10 mm/ each having five replicates)

Table 2: Toxic chemical elements in the pulp and paper sludge – PPS (Tisoňová 2012)

Type of PPS	**Amount [mg.kg^{-1}]**								
	As	**Cd**	**Cr**	**Cu**	**Hg**	**Mo**	**Ni**	**Pb**	**Zn**
PPS-1	7.9	2.8	8.7	85.0	0.3	2.8	2.8	15.0	182.0
PPS-2	14.7	0.5	15.4	56.9	0.8	3.5	2.4	5.2	77.8
PPS-3	1.0	0.5	8.9	17.1	0.7	6.4	4.2	8.4	25.6

For a potential application of the PPS insulations in practice, there a very important will be mainly their healthiness, *e.g*. removal of the most dangerous chemical elements – arsenic, chrome, mercury and lead. However, it can be technically and economically a very difficult task.

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Characterization tests for insulation boards made from corn cob and natural glues

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Keywords: insulation board, corn cob, natural glue, eco-efficiency

In recent years there has been a growing interest in developing news solutions for more ecologic and efficient construction, including natural, renewable and local materials, thus contributing in the search for more efficient, economic and environmentally friendly construction. Several authors have assessed the possibility of using various agricultural sub products or wastes, as part of the effort of the scientific community to find alternative and more ecologic construction materials.

Corn cob is an agricultural waste from a very important worldwide crop. Natural glues are made from natural materials, non-mineral, that can be used as such or after some modifications to achieve the behaviour and performance required. Two examples of these natural glues are casein and wheat flour-based glues that were used in the present study. Boards with different compositions were manufactured, having as variables the type of glue, the dimension of the corn cob particles and the features of the pressing process.

The tests boards were characterized with physical and mechanical tests, such as thermal conductivity (λ) with a ISOMET 2104 and 60 mm diameter contact probe, density (ρ) based on EN 1602:2013, surface hardness (SH) with a PCE Shore A durometer, surface resistance (SR) with a PROCEQ PT pendular sclerometer, bending behaviour (σ) based on EN 12089:2013, compression behaviour (σ_{10}) based on EN 826:2013 and resilience (R) based on EN 1094-1:2008, with a Zwick Rowell bending equipment with 2 kN and 50 kN load cells (Fig. 1), dynamic modulus of elasticity (E_d) with a Zeus Resonance Meter equipment (Fig. 5) based on NP EN 14146:2006 and water vapour permeability (δ) based on EN 12086:2013.

The various boards produced were characterized according to the tests and the ones with the best results were C8_c8 (casein glue, grain size 2,38-4,76 mm, cold pressing for 8 hours), C8_c4 (casein glue, grain size 2.38-4.76 mm, cold pressing for 4 hours), F8_h0.5 (wheat flour glue, grain size 2.38-4.76 mm, hot pressing for 0,5 hours), FEV8_h0.5 (wheat flour, egg white and vinegar glue, grain size 2.38-4.76 mm, hot pressing for 0,5 hours) and $FEVH_6$8_c4 (wheat flour, egg white, vinegar and 6 g of sodium hydroxide glue, grain size 2.38-4.76 mm, cold pressing for 4 hours).

Figure 1: Zwick Rowell bending equipment with 2 kN (left) and 50 kN (right) load cells

Taking into account the various boards produced and respective test results the type of glue and the pressure and pressing time are very important factors which strongly influence the final product.

The results obtained confirmed the initial hypotheses that these boards have potential as a thermal and, eventually, acoustic insulation material, to use as coating or intermediate layer on walls, floors or false ceilings. This type of board has a high mechanical resistance when compared with traditional insulating materials, as can be seen in (Table 1).

Table 1: Comparison between the board with corn cob and natural glue which showed better results ($FEVH_6 8\_c4$) and some traditional insulation materials

Insulation boards	**Board with corn cob and natural glue**	**ICB**	**XPS**	**EPS**	**Rockwool**
Thickness (mm)	31	10 a 300	30 e 40	20 a 100	30 a 100
ρ (kg/m^3)	502	110 a 120	30	20	145
λ (W/m.ºC)	0.114	0.037 a 0.040	0.035	0.036	0.038
δ (mg/m.h.Pa)	0.09	0.015 a 0.045	0.004 a 0.009	0.009 a 0.020	0.400
σ (kPa)	1043	≥ 130	-	150	-
σ_{10} (kPa)	1690	≥ 110	200	100	≥ 45
Technical details	-	Sofalca	Wallmate / Floormate	CIN	CIN

The integrity of these boards seems to be maintained even in higher humidity environments. However, due to biological susceptibility and sensitivity to water, they would be more adequate for application in dry interior conditions.

Using of peat as insulation material. Properties and Technologies

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Keywords: peat, bots,

The presentation will be based on the uses and researches of the thermal and other properties of the peat in Estonia. Peat is very useful and ordinary material in the field of cattle breeding and now in bio-energy, but in previous times it was used as insulation material. The biomass has good properties for these purposes.

Peat is a natural resource and a renewable material. Its accession is *ca*. 0.9mm per year, in Estonia *ca.* 9,077 million m^3/per year. There are two types of peat depending on the formation and application field. One of them is well-decayed swamp-peat (older; nutrition from groundwater), which is used mostly as heating material and less as a fertiliser, gardening or in medicine. The other is little-decayed pocosin- or bog-peat (younger; nutrition from freshet), used in the agriculture as litter in cattle breeding.

The first purpose of the investigation was to evaluate how peat was used in building structures in previous times and collect the data together. The second one was to find out the new technologies of how to do this in the new era when the structural engineering focuses on ecological methods. This means assessing how the biomass of the peat may be used as bio-based thermal insulation without harmful impact especially to the building structures of timber.

The little-decayed pocosin may practically be used as insulation material. The best way to use it in the timber-frame structures is as blocks from the natural biomass (Fig. 1). The wall structures what have empty gaps inside, which can be filled with peat milled from the upper layer of the biomass. Pressed peat plates can used also as covering material (Fig. 2).

The properties of peat using it inside timber structures are good. The plates pressed of peat have light density (48 kg/m^3) and enough tensile strength (126 kPa). It has good resistance to mould and microbes. This is possible because peat moss is a sour fibre by nature. The thermal properties of peat-plates are good too (l10 = 0,037 W/m·K). The only problem is that the natural fire resistance class is too low (E), but there are lot of possibilities to treat it. The insulation plates are easy to handle and cut on the building site. The plates tolerate moisture and water extremely well and do not need a vapour barrier. The material does not change form in different temperatures and is recyclable after use.

Figure 1. Carved little-decayed pocosin from Lavassaare bog (AS Tootsi Turvas)

Figure 2. Konto-insulation plate of peat and timber fibre; #50 and 75mm (Konto OY)

In the future it will be necessary to investigate the properties of insulation material of peat with other components in depth, including stability in time, resistance to the different weather conditions, sound insulation qualities, the ability of biological resistance, and expansion and declension with changes in temperature and humidity conditions through the field tests.

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Moisture buffering properties of various hardwood species

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Keywords: moisture buffering, adsorption, hardwood

Moisture buffering has been studied from various perspectives, but research has mainly focused on softwood species, especially on spruce and pine. Sometimes, especially in the field of construction, wood has been presented without specifying the species. Nevertheless, there is a need for information regarding the moisture buffering behaviour of wood, since designers and architects have a growing interest towards the use of wood in interiors. Information of the performance of wood material in different temperature and humidity conditions should be easily accessible to support the aim to create functional wooden surfaces. Another significant perspective is different surface treatments and their effect on the performance of wooden surfaces, *e.g*. moisture buffering capacity.

This poster will present the results from the initial screening of the performance of six hardwood species in two humidity levels: RH33 and RH75. The species in this study were ash, birch, black alder, elm, maple and oak.

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Investigations of the properties of artificial veneers finished in Hot Coating technology

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Keywords: veneer, finishing, hot-coating, UF resin, property

Introduction

In woodworking industry people are looking for ecological technologies for finishing of wood and wood based materials surfaces. In recent years dominated the following trends in the range of application of lacquer coatings, in which seeks to receiving of coatings with excellent aesthetic-decorative features, very good physico-mechanical properties and high utility resistance, implementation of efficient techniques for energy saving application and hardening of lacquer coatings, reducing drying time, minimizing of the number of layers and reducing the consumption of products, environmental performance, and reduce the cost of waste of lacquer products (Krystofiak, Lis and Proszyk 2011). In this process has not the necessity drying up before applied of acrylic UV lacquer. So the very essential reduction of the technology of finishing, consisting into limitation of the number of operation, not large industry productive area, low costs of technological machines (Anonymous 2008). Very interesting solution within the range products designed to finishing of artificial veneers surfaces in finish version are polyurethane (PUR) lacquers, which applied in the Hot Coating (HC) technology (Proszyk, Krystofiak and Golecki 2005). Under the name HC system one is comprehensible process consisting with hot application (100-140 ^{o}C) of the thermoplastic, reactive PUR polymer, basing itself on isocyanate prepolymers, which solidifies into the coatings, in consequence of cooling in the very short time (2-6 s), surrendering then, within a period of 3-5 days of the transformation to the duroplast form. This system is commonly used for finishing of flooring elements (Proszyk *et al*. 2006, 2007).

Experiments

For experiments UF adhesive resin with the trade name Silekol MZ (product of SILEKOL Comp.) was used and preparing glue mixtures in compliance with recommendations of producer (mixing resin and hardener 10% maleic anhydrite in proportion 100:2.5 p.b.w). From the KLEIBERIT Comp. 8 kinds of artificial veneers (at the thickness 0.28±0.04 mm) in finish version finished with PUR lacquer coatings in HC technology (application temp. 140±1 ^{o}C, amount of spreading 80 g/m^2). As a substrate MDF board was used about the density of 700±20 kg/m^3, MC 8±1% in the dimensions 300 x 120 x 18 mm. Glue mixture was applied with plastic applicator in the quantity 70 g/m^2. Veneering in the prototype hydraulic press was performed (at pressure 0.5 MPa, pressing temp. 20±0.5 ^{o}C, pressing time 15 min). Veneering board elements after 168 h of air conditioning (23±2 ^{o}C and 50±5%) to thermal aging accordingly to the procedure described in PN-

88/F-06100/07 standard were subjected. Gloss with the use of photoelectric method, metamery effect, adherence with pull-off method and wettability after 3, 6 and 9 aging cycles were determined.

Results

In the table 1 results of gloss was given.

Table 1: Results of investigations of gloss cross and alongside of selected artificial veneers in function of number of aging cycles

Marking of veneers	Statistical data	Number of cycles							
		0		3		6		9	
		cross	Alongside	cross	alongside	cross	alongside	cross	alongside
		Gloss							
	x	13.5	10.8	13.0	11.0	12.8	10.5	12.7	10.3
	v [%]	6.7	9.3	5.4	8.2	4.7	8.6	5.5	7.8
	Note	Half-mate							
		29.9	23.7	27.6	21.8	26.6	22.0	27.0	22.0
	v [%]	7.4	7.6	5.4	6.9	7.1	8.2	7.4	3.6
	Note	Half-mate							

x – average, v – coefficient of correlation

Veneers showed and gloss degree expressed in the wordy estimation – half mate. Thermal aging test did not change this parameter.

Conclusions

Tested veneers in finish version with PUR HC coatings system with high aesthetic-decorative features were characterized, stable in the condition of the simulated thermal aging test. Veneers showed very good adherence to the MDF substrate, and gloss degree expressed in the wordy estimation – half mate. Tested coatings showed the metamery effect.

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Utilisation of sorghum waste for particleboard production -density profile

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Keywords: particle boards, sorghum, density profiles, properties, radioisotope ^{241}Am

It would seem that with appropriate treatment almost any agricultural residue may be used as a suitable raw material for the wood-based panels like particle- and fibreboard production (Barbu et al. 2013).

The paper is oriented on experimental verification of possibility of sorghum utilisation for manufacturing three layer particle boards. In laboratory conditions there were produced boards with dimensions of 360x360x16 mm and density 720 kg.m^{-3} in four variants with the following ratios of sorghum particles : wood particles: 3 : 0, 0 : 3, 1 : 2, 2 : 1. In all variants there were determined density profile and standard physical and mechanical properties (Vrábľová *et al*. 2006).

For density profiles determination was used apparatus constructed in laboratories of the Faculty of Wood Sciences and Technology, Technical University in Zvolen (Fig. 1). Source of the gamma radiation was a low-energy radiant AMG 50. It works with the radioisotope ^{241}Am having the energy of 59.5 keV, and its output power is 2.0 GBe. The shift of the samples was always after each 0.2 mm.

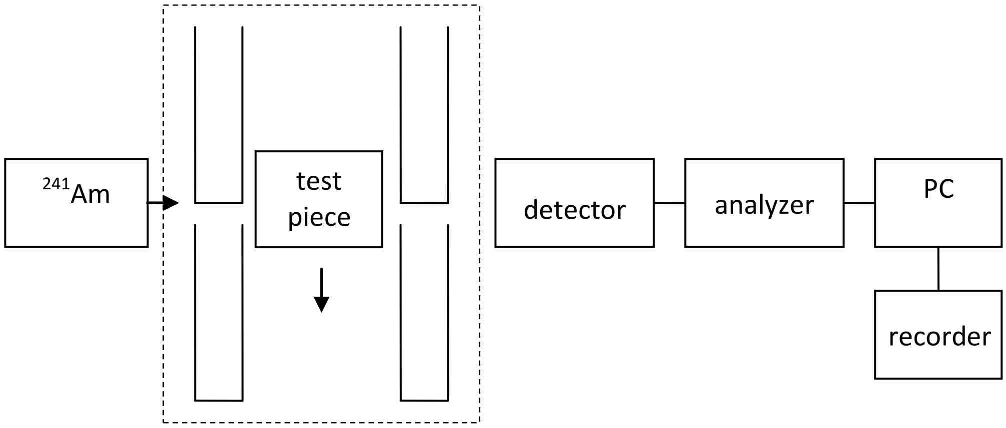

Figure 1: Working flow diagram of the analyzer of density profiles

The analyzer scanned the density profiles of respective samples in one plane. The intensity of the gamma-radiation after crossing the slots is evaluated by the NaJ (TI) detector which is attached to the single-channel spectrum analyzer IH 10 made by the firm STADOS Prague, Czech Republic. This analyzer is furnished with IMS2 interface that makes it possible to control measure with personal computer (Bahýl 1992).

The results of this experiment are shown in Fig. 2

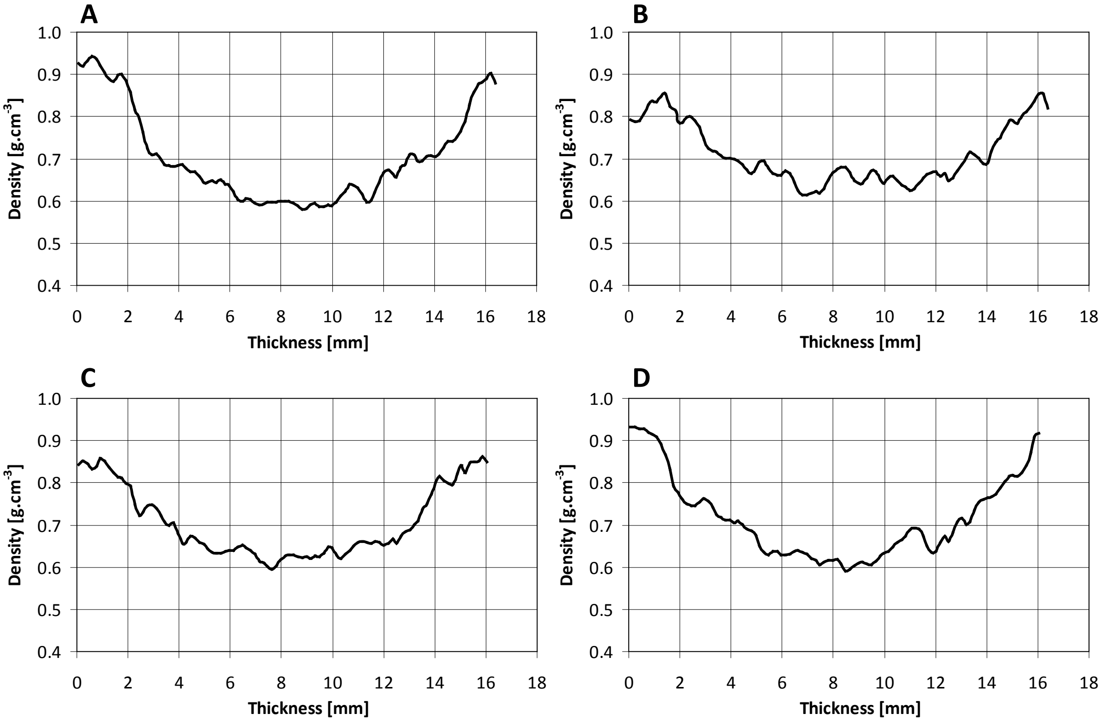

Figure 2: Density profiles: **A** - sorghum particles : wood particles 3 : 0, **B** - sorghum particles : wood particles 0 : 3, **C** - sorghum particles : wood particles 1 : 2, **D** - sorghum particles : wood particles 2 : 1.

Boards with higher proportion of sorghum cause significant densification of surface layers of boards which implies that sorghum ability to densify appears higher than for wood. The obtained research results indicate possibilities of the utilisation of sorghum particles to manufacture particle-boards, either as the basic raw material or as an additive to traditional wood raw material.

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COST Action FP1407: Understanding wood modification through an integrated scientific and environmental impact approach (Acronym: ModWoodLife)

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Keywords: modification, processing, LCA, EPD, cascading

The forest-based sector can become a leader in achieving the European Commission's ambitious target of reducing CO_2 emissions with innovative production technologies, reduced energy consumption, increased wood products recycling, and reuse. Apart from these undoubted environmental benefits, the use of forest products in long life products, such as built environment applications, allows for the possibility of extended storage of atmospheric carbon dioxide. Wood modification (chemical, thermal, impregnation) is an assortment of the innovative processes currently being adopted. Though many aspects of these treatments are known, the fundamental influence of the process on product performance, the environment, and end of life scenarios remain unknown. It is essential to integrate interactive assessment of process parameters, developed product properties, and environmental impacts. To optimise modification processing for minimized environmental impacts, much more information must be gathered about all process related factors affecting the environment (VOC, energy use, end of life use, etc.). COST Action FP1407 will investigate modification processing and products design with emphasis on their environmental impacts. This will require analysis of the whole value chain, from forest through processing, installation, in-service, end of life, second/third life (cascading) and ultimately incineration with energy recovery.

The main aim of this Action is to characterise the relationship between modification processing, product properties, and the associated environmental impacts. This includes the development and optimisation of modified processing and quantification of the impacts of emerging treatment technologies compared to traditional processing and alternative materials to maximise sustainability and minimise environmental impacts. COST Action FP1407 will advance research in the field of wood modification and allow significant contributions to the goals of European and global resource efficiency and a low carbon economy.

The key research and activities of this Action, which are presented in Fig. 1) are: Modification processes and resultant products; Environmental impact assessment; Environmental products declarations; Integration, dissemination and exploitation. The Action's members, academic and industry researchers and other experts will be forming an international and interdisciplinary research forum where knowledge and expertise from forestry, wood, biotechnology, chemistry, physics, engineering, environmental engineering, design/architecture, building physics, mathematics, etc., will be grouped into 4 Working Groups (WG): WG 1: Product Category Rules; WG 2: Life Cycle Assessments; WG 3: Environmental products declarations; and

WG 4: Integration, dissemination and exploitation. With scientific excellence and strong industrial input the Action will fill existing knowledge gaps and deliver new data in the area of wood modification including:

- Holistic understanding of environmental impacts during the full life cycle;
- Use phase - role of maintenance, repair, refurbishment, replacement over the full life cycle;
- End of life – deconstruction, demolition, waste processing;
- Benefits and loads beyond the system boundaries – reuse, recovery, recycling potential;
- Modified wood in cascade wood use;
- Country specific and geographic factors; Harmonisation of PCRs and EPDs; Internationally agreed accounting procedures; EPDs of modified wood; Upgrading concepts and end of life options of modified wood; Standardisation – whole life cycle.

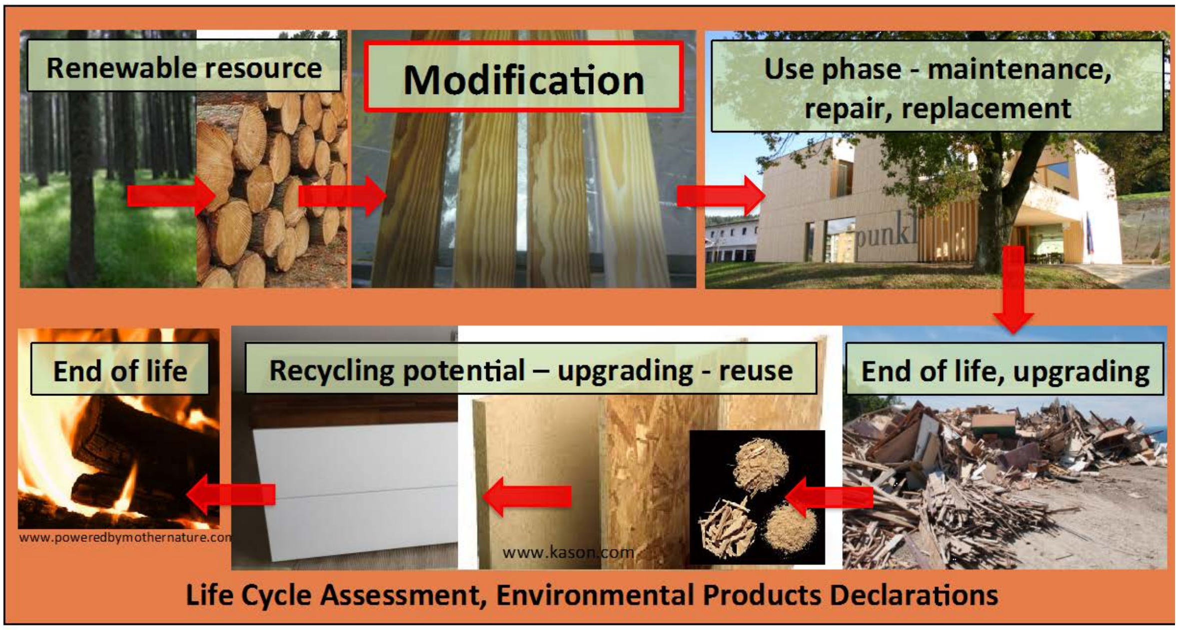

Figure 1: COST Action FP1407 ModWoodLife

It is possible to assess the degradation stage of bio-based materials with an “objective” approach?

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Keywords: bio-materials, degradation degree, visual assessment, NIR

Bio-based materials due to their biological nature can undergo modification during their service life that can be caused by mechanical, environmental or biological agents. In a consequence significant changes within physical, mechanical and chemical properties are occurring and drop of material performance is expected. On the other hand biodegradability is becoming a desirable feature for several everyday products, such as packaging or wastes.

The commonly used method for assessment of the biodegradation stage is based on visual estimation of degraded samples according to specific standards (prEN 252, CEN/TS 12037). The alternative might be measurement of mass loss (in case of decayed or waterlogged wood) or breaking length (in case of assessment of mechanical properties pf paper). The goal of this work is to apply NIR spectroscopy as an objective method for the evaluation of degradation degree of several bio-based materials. NIR has been selected as an alternative to the standard methods for evaluation of fungal degradation on paper products. Examples of successful application of NIR for assessment of wood degradation after weathering and waterlogging will be also presented.

Sixteen paper types of coniferous sulphate bleached pulp were created with varying content of additives (0, 2, 3, and 5% addition of cationic starch and resin adhesive). *Chaetomium globosum* and a mixture (1:1:1) of *Aspergillus niger, Penicillium funiculosum, Trichoderma viride* were selected as degrading fungi. Visual evaluation of the fungal growth degree on the paper samples was estimated according to the four point scale. Grade “3” corresponds to no presence of fungi, where grade “0” indicates very abundant growth with surface entirely colonized by test fungus mycelium. Samples were measured in ten independent repetition series on the 2nd, 4th, 7th, 10th and 14th day after infestation. An average value of the fungal growth degree was computed for all corresponding series at each progress step (infestation day) and this value was used as the fungal growth indicator.

The device utilised for NIR measurements was Vector 22-N spectrophotometer (Bruker Optics GmbH, Ettlingen, Germany). The measured spectral range was between 4000 cm^{-1} and 12000 cm^{-1} with resolution of 8 cm^{-1}. Each degradation stage of all papers was represented by five paper strips. The paper surface was mechanically cleaned from the mycelium before NIR spectra were recorded. All measurements were made in an environmentally controlled room (20± 2°C and 65 ± 5% RH) in order to minimize effects of the temperature and the moisture variations. Partial least squares regression (PLS) were used for data analysis and mining (OPUS 7.0 Bruker Optics GmBH).

Results of visual assessment were used as reference values for the calibration of NIR system and development of dedicated chemometric models. The Partial Least Squares algorithm allowed correlation of the reference data (infestation degree) with NIR spectra. The QUANT routine was used for determination of optimal model settings. The prediction capabilities of PLS models are presented in Figure 1. The coefficient of determination (r^2) was 0.73 for the infestation degree.

It is clear that the real-life fungal growth is a continuous variable, when the “degree” is discreet (the border between classes is fuzzy + the evaluation by the expert person is subjective). As a result, not “class” is obtained but “an indicator”, being descriptor of the fungal growth mechanisms. In a consequence, the PLS model performance was not very high, as may be expected. Nevertheless the “discrete nature of the reference value” is somehow diminished by high number of measurement points. The presented PLS model might be used as an alternative to the visual assessment usually performed. Even if the methodology is based on subjective data it can be very useful for the routine laboratory work and may minimize the subjectivity of the data provided by personnel.

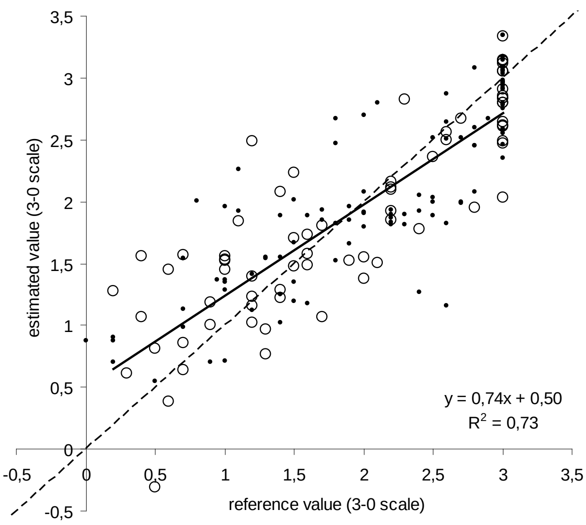

Figure 1: Prediction of infestation degree of paper with FT-NIR

Effect of environmental exposure on tensile characteristics of wood-plastic composites filled with low-grade woody biomass

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Keywords: accelerated weathering, durability, low-grade woody biomass, mechanical properties, wood plastic composite

Wood plastic composites (WPCs) are commonly made using commercial grade wood flour, which is increasingly becoming a commodity as availability governs its price. However, there are alternative sources of woody biomass that are currently underutilized (Thompson *et al.* 2010; Karas and Muszyński 2011). Previous work proved that commercial pine flour in WPCs with high-density polyethylene (HDPE) matrices could be substituted with a variety of low-grade woody biomass without significantly impairing characteristic mechanical properties (Karas 2010). The objective of this study was to investigate the effect of low-grade woody biomass content on the mechanical properties (tensile strength, elastic modulus, and specific work to failure) and WPC resistance to artificial ageing (accelerated weathering and soak-freeze-thaw treatments).

In this study WPC test specimens were created using a single screw extruder and by mixing HDPE, polyvinyl chloride (PVC), and polylactic acid (PLA) matrices with wood flour from virgin pine flour (CF), logging slash residue (LF), and urban demolition (UF) wood sources. By weight, wood flour made up 20%, 40%, and 60% of the composites. Specimens from each combination were subjected to one of two ageing treatments. The first treatment was applied using a QUV accelerated weathering tester (Q-LAB, Westlake, OH, USA) which generated ultraviolet (UV) light, condensation, and heat according to ASTM G154 Cycle 1. The second treatment was a soak-freeze-thaw (SFT) cycle developed by Wang (2007). All of the specimens were then tested using an ElectroPlus E1000 test machine (Instron, Norwood, MA, USA). The assumptions for ordinary least squares linear regression and analysis of variance were met and these methods were used for comparative analysis.

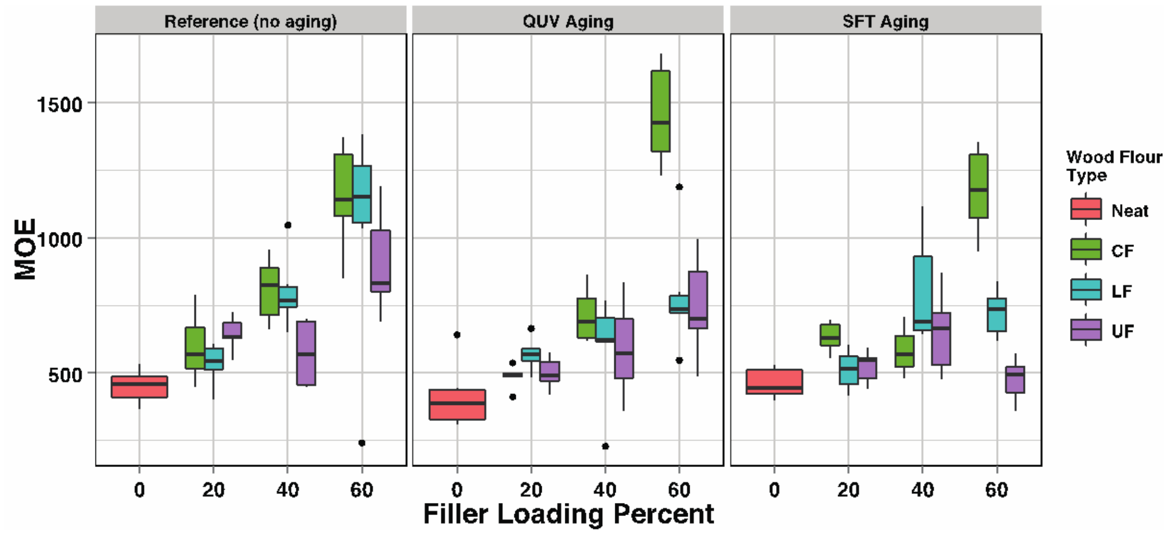

Figure 1: Observed elastic modulus for HDPE matrices separated by aging method, wood flour type and loading percent.

In the case of HDPE, the observed MOE revealed CF outperformed UF in the reference specimens, and clearly outperformed LF, UF and Neat specimens (Fig. 1). Additionally, amongst the HDPE specimens, CF at 60 % loading was more resistant to aging. However, the linear regression model (adjusted R^2: 0.818) strongly suggests the presence of a 3-way interaction in the observations (p-value: 0.0001, making reliable generalizations regarding an individual factor challenging.

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Performance Testing of Hemp Shives in the Particleboard Core Layer

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Key words: non-wood cellulosic materials, hemp shives, properties, heating value

The aim of the paper is to prove the trouble-free presence of hemp shives in the core layer of particleboard with the help of tests of heating value and energy efficiency. Hemp is a commonly used term for high-growing varieties of the Cannabis plant and its products, which include fiber. It is possible to use hemp shives as the partial substitute of wood in the particleboard manufacture. The addition of hemp shives to wood particles in the core layer of particleboard cannot influence the particleboard properties.

The addition of hemp shives affects positively the static three-point bending strength of particleboard, even the boards with the addition of hemp shives in the core layer showed better results of bending strength than unmodified particleboard. The tests of modulus of elasticity in bending, tensile strength perpendicular to the board plain, swelling after 2 and 24 hours, and moisture content were performed as well.

Heating values were obtained either by adiabatic or isoperibol bomb calorimetry following ISO 1928 or ASTM D5865. An adiabatic bomb calorimeter detects the net energy liberated from combustion by maintaining a constant water bath temperature about the bomb, which is TCal. An isoperibol bomb calorimeter detects the net energy liberated by accurately monitoring the water bath temperature, its resultant average value being TCal. Many modern bomb calorimeters are automated to run at a programmable TCal. In North America various labs use the temperature 27, 28.5, 30 or 35 ^{o}C. In Europe the determination of heating value at 25 ^{o}C is used, this temperature was used also in our lab.

The case for various temperatures lies in the definition of higher heating value (HHV) as obtained from a bomb calorimeter: the energy from products formed are relative to the equilibrium temperature, this includes, of course, the water produced as reduced to the liquid state. Energy liberated from a bomb calorimeter is relative to the equilibrium temperature at which the bomb functioned.

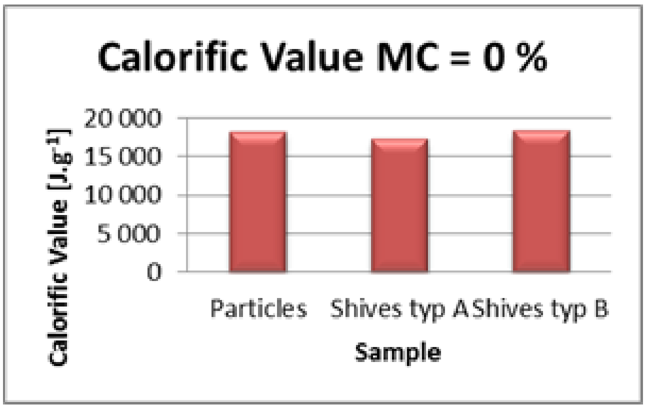

Figure 1 Calorific Value of Particles and Hemp Shives (Moisture Content = 0 %)

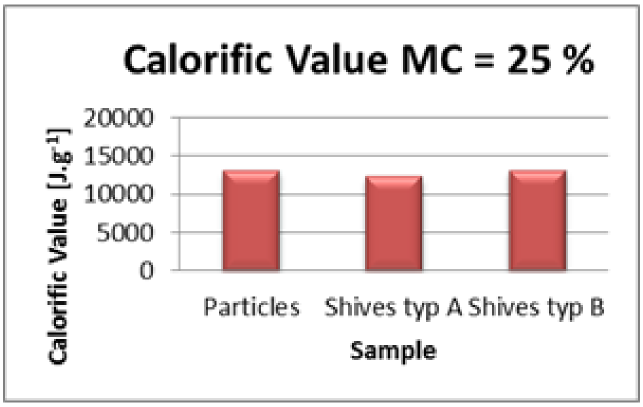

Figure 2 Calorific Value of Particles and Hemp Shives (Moisture Content = 25 %)

Figures 1 and 2 follows that combustion heat and calorific value of wood particles and hemp shives, which were intended for further manufacture of particleboard, are about the same level. This result was confirmed in both mixtures, where different factions were represented. The mixture itself, its fractional composition, was fully satisfied for the requirements for the particleboard manufacture, whether it was wood particles or hemp shives.

The experiment was performed consequently with the mesh size fraction which is equal to 0.5 mm. Combustion heat and calorific value of wood particles compared with hemp shives were also in this case at a similar level.

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Fungicidal properties of ligno-cellulosic insulation and bio-building materials

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Keywords: wood decay fungi, building boards, wood fibre, wood plastic composites, thermal insulation

Consumption of wood based ligno-cellulosic insulating materials in the building industry increases from year to year. In spite of increased consumption, there is a lack of data on the performance of these materials against wood decay fungi that can appear on material in case of condensation or water leakage. The producers usually focus only on data important for the building physics. The majority of producers do not list the performance of the insulation materials against fungi or insects, despite the fact that fungi are the most important threat to wood and lignocellulose based materials in central and northern Europe. In this study, the durability of 12 frequently used materials: five different insulation materials based on wood fibre, hemp fibre insulation, cellulose loose-fill insulation, OSB board, plywood and wood plastic composites were exposed to three brown rot fungi (*Antrodia vaillantii*, *Gloeophyllum trabeum* and *Serpula lacrymans*) and three white rot fungi (*Trametes versicolor, Hypoxylon fragiforme* and *Pleurotus ostreatus*) according to the EN 113 procedure. Two types of cellulose loose-fill insulation were tested: the first containing only boron compounds (cca. 10% w/w) (CEL) as fire retardant and the second with fire retardancy mixture of light metal compounds and much lower portion of boron compounds (3% w/w) (CEL1) for resistance against wood decay fungi and moulds. The second aim of our work was to determine, how thermal conductivity coefficient λ of cellulose loose-fill insulation depends on moisture content and density.

The average mass loss of the tested insulation materials after exposure to the fungi was in general higher than the mass loss of Norway spruce (*Picea abies*) and/or beech wood (*Fagus sylvatica*), indicating that the resistance of these materials against fungi is lower than the resistance of control spruce or beech wood. The majority of the insulation materials were extremely susceptible to fungal decay, particularly brown rot. This result was to be expected, since most of the composites contain only adhesives, water repellents and fire retardants and do not contain biocides. In order to limit fungal decay and achieve the desired service life, their moisture content must be lower than 20% (Zabel and Morell 1992). Despite the lower portion of boron compounds of cellulose loose-fill insulation (CEL1) both types of cellulose loose-fill insulation fulfil the requirements of the EN 113 standard. Relatively low loadings are required for protection of wood against wood decay fungi, up to 0.8 kg m^{-3} BAE (boric acid equivalent) (Lesar and Humar 2009). On the other hand, considerably higher retention is necessary for protection against mould and staining fungi (2 kg m^{-3} BAE) (Fogel and Lloyd 2002).

Table 1: Description and basic information about the materials used in the investigation

Abbrev.	Description	Abbrev.	Description
NS	Norway spruce	**HEMP**	Hemp fibre insulation
BE	Beech	**LV1**	Wood fibre insulation
OSB	OSB/3 construction board, thickness 18 mm	**LV2**	Flexible insulation made of wood fibres
PL	Poplar plywood, thickness 18 mm	**LV3**	Façade insulation made of wood fibres
WPC1	Wood plastic composite	**LV4**	Wood fibre insulation
WPC2	Wood plastic composite	**LV5**	Wood fibre insulation designed for sound insulation
WPC3	Wood plastic composite	**CEL**	Cellulose loose-fill insulation - boron based only

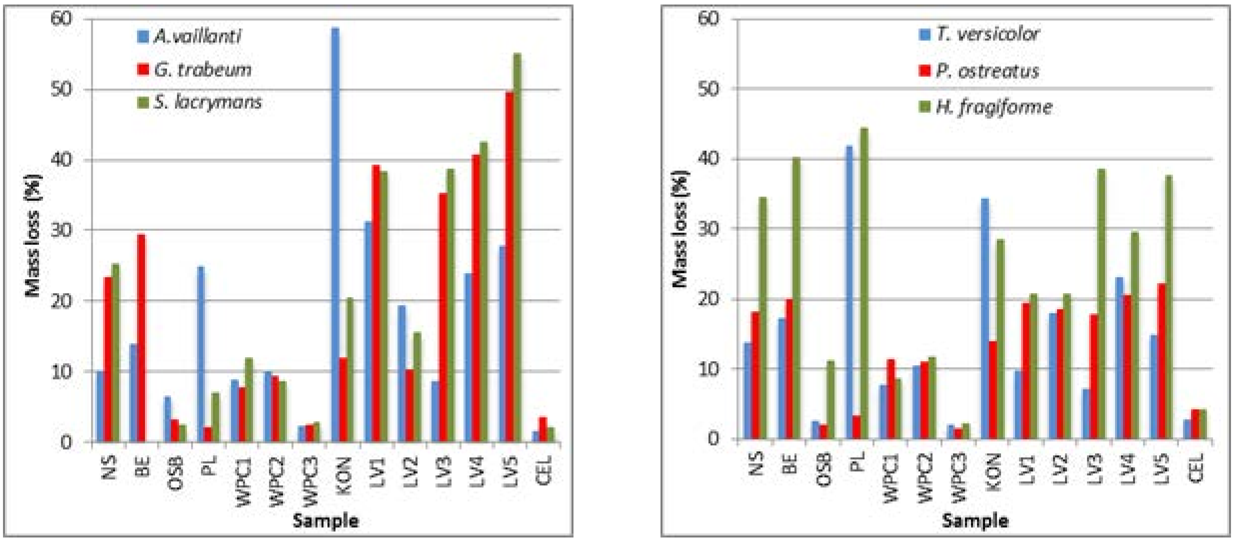

Figure 1: Mass loss of tested insulation and construction materials after 16 weeks of exposure to brown rot fungi (left) and white rot fungi (right)

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Bioassay of selected fungicide on thin layer chromatography against moulds

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Keywords: bioautography, screening test, fungicide

The main reason of low durability of wood is biodegradation, caused by organisms such as fungi, bacteria and insects. It limits the usefulness of the wood and leads to its structure changes, as well as physical and chemical properties. Appropriate preventive measures allow one to protect wood in high humidity when it is most sensitive to these factors, inhibiting its rapid degradation. Globally, the most common and most dangerous biological factor to wood in constructions and in architectural monuments are decaying fungi and moulds.

In order to protect wood against decaying fungi, variety of wood preservatives are used. They are expected to be both long-term effective and environmentally friendly. The efficiency and stability of the formulations for wood preservatives depend mainly on active ingredients - biocides. For the preliminary determination of the biological activity of the potential biocides, quick laboratory tests – screening are used (Munoz-Olivas 2004). There are many methods to measure the impact of chemicals on the fungi growth but one of the simplest and fastest methods is bioautography-TLC.
Bioautography microbiological testing is a commonly used screening to identify antibacterial and antifungal compounds (Choma and Grzelak 2011). Performed bioautography screening method combined with thin layer chromatography is more sensitive than other screening methods for determination of biocides properties (Homans and Fuchs 1970). These rapid test methods are useful in the search for biocides that may be acceptable as wood preservatives and in coatings.

The aim of the present work was to analyze the minimum inhibitory concentration (MIC) of selected fungicides (1,10-di(3-hydroxymethylpyridinium) decane dibromide, 4,5-dichloro-2-octyl-2H-isothiazol-3-one, dichloro-2-n-octyl-4-isothiazolin-3-one with 2-octyl-2H-isothiazol-3-one, n-alkyl(C12-18)-N,N-dimethyl-N-benzylammonium chloride) using bioautography-TLC method and compare the results of screening with the results of mycological test performed on wood. For this purpose fungistatic activity of selected formulations was tested using bioautography-TLC to determine MIC of fungal growth. A visual assessment of *Aspergillus niger* van Tiegh growth on plate in accordance with the four-point scale of intensity mycelium growth is presented in Table 1.

Table 1. Rating-scale of fungal growth

Rating	Fungal growth on surfaces
0	no visible growth under the microscope
1	invisible growth with the naked eye but are clearly visible under the microscope
2	visible growth with the naked eye, growth of hyphae without spores
3	visible growth with the naked eye, sporulation mycelium
4	intensive growth, covering the entire surface of the test

Minimal inhibitory concentration for 4,5-dichloro-2-octyl-2H-isothiazol-3-one is equal to 0,001%, for dichloro-2-n-octyl-4-isothiazolin-3-one with 2-octyl-2H-isothiazol-3-one, and n-alkyl(C12-18)-N,N-dimethyl-N-benzylammonium chloride is equal to 0,1%. (1,10-di(3-hydroxymethylpyridinium) decane dibromide has fungicidal activity at a concentration of 1%. The next step was the impregnation of pine wood with selected biocides in the indicated concentrations and the obtained results in both biological tests were compared. The results show that the bioautography-TLC method enables fast determination of fungicidal activity of selected substances and their successful application as an active component in wood preservatives.

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Acknowledgments:

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Insights from the 57th LCA discussion forum, "Life cycle assessment in the building sector: analytical tools, environmental information and labels".

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Keywords: EeBGuide Info Hub, environmental impacts, harmonisation, 2000-Watt Society

In December 2014 the 57th LCA Discussion Forum was held in Zurich, Switzerland and focused on life cycle assessment in the building. The LCA Discussion Forum is a Swiss platform to exchange and share ideas, concerns and best practices between LCA practitioners working in industry, consulting, legislation, and research. At the forum European and Swiss legislators, LCA researchers, LCA practitioners and industry representatives discussed the analytical tools, environmental information, and labels in the building sector. At the Forum's "open floor" session COST Action FP1303 was presented. Videos of all publications are publicly available on http://www.multimedia.ethz.ch/misc/lca/2014-57. Below several key aspects discussed at the LCA Forum are briefly presented.

The forum provided an overview of different tools, information and labelling schemes applied in Switzerland, Germany, France, and Austria. The Swiss "2000-Watt Society", which was developed at the Swiss Federal Institute of Technology (ETH) in Zürich, was presented. The City of Zurich decided to use the "2000-Watt Society" approach to tackle climate change and address resource availability in the future. This model for energy policy demonstrates how it is possible to consume only as much energy as worldwide energy reserves permit and is justifiable in terms of the impact on the environment. Furthermore, in the City of Zurich the "2000-Watt Society" is seen as a tool to achieve a higher quality of life. Therefore, among other activities, almost all new construction, including housing estates, school buildings and retirement homes in the City of Zurich follow the Minergie Standard (for low-energy housing).

Special focus was given to future developments in European legislation, harmonisation and research. Among the presentations on these topics was the EeBGuide Info Hub. The EeBGuide Info Hub is the outcome of the European research project 'EeBGuide – Operational guidance for Life Cycle Assessment Studies of the Energy-Efficient Buildings Initiative' that aimed to develop guidance documents for energy-efficient building LCA studies. The InfoHub is built on reference documents such as the ISO 14040-44 standards, the EN 15804 and EN 15978 standards as well as the ILCD Handbook. In the “EeBGuide Guidance Document Part B: buildings” 104 important aspects have been identified for improving building LCA studies that aim to be compliant both with CEN TC 350 standards and with the ILCD Handbook. They cover the aspects concerning Module A – Product and construction process stage, Module B – Use stage, Module C – End-of-life stage, and Module D – Benefits and loads beyond the system boundary. For every stage the guidance suggests how to deal with specific issues, what should be taken into account when performing the LCA of a building.

The representative of Cement Sustainability Initiative (CSI) presented a global EPD Tool for cement and concrete, a web-based calculation tool for primary data input based on PCRs of unreinforced concrete, concrete, and cement. The PCRs focus on the impact of production from cradle to gate for B2B purposes. The CSI is providing the EPD Tool to its members and the wider industry to enable the development of EPDs. The CSI PCRs are registered under the International EPD® System (Environdec). They are based on the ISO standard for EPDs (ISO 14025:2006) and comply with the European standard for construction products (EN 15804:2012).

A presentation about modelling the use phase of building materials discussed the influence of indoor emissions on LCA of buildings and delivered the conclusion that the emission to indoor air cannot be assessed with the existing ECO-factors and that data on emissions over longer time periods of almost all building materials are missing.

The main conclusion of the Forum was that there is a need for harmonization of LCA methodology in the building sector. COST Action FP1303 was identified as network that aims to contribute to the harmonization. Buildings are significant consumers of energy and are getting more and more attention in this regard. Therefore, COST Action FP1303 should take an active role in future development of analytical tools, delivering the environmental information of bio-based building materials, and development of labelling schemes. They should participate in the next LCA Discussion Forums that will take place in 2015, especially the DF 60 Environmental use of wood resources, which will take place on December 4th, 2015 in Zurich and aims to provide new perspective on an ecological use of wood resources that is relevant to scientists, policy makers and practitioners.

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Analysis of dimensional stability of thermally modified wood exposed to re-wetting cycles

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Keywords: thermal modification, dimensional stability, wetting-drying cycles, anti-swelling efficiency, heat treatment

The dimensional stability of thermally modified Beech (*Fagus sylvatica* L., 0.72 g/cm3), poplar (*Populus alba* L., 0.39 g/cm3), and spruce (*Picea abies* L. Karst., 0.41 g/cm3) wood exposed to several wetting-drying cycles was analysed. Specimens of dimensions 15×15 ×15 mm^3 were thermally modified using a small-scale laboratory heat-treatment chamber (Katres spol. s r.o., CZ) at 180 and 200 °C. The schedule of the five-stage thermal modification process throughout 50 h was achieved with a temperature control system (Figure 1). The maximum temperatures (180 or 200 °C) were maintained for 3 h. The mass loss (ML) of thermally modified specimens was determined immediately after the end of the modification process in order to evaluate the degree of the modification. Afterwards, the radial, tangential, and volumetric swelling, anti-swelling efficiency, water absorption, water repellence efficiency, and mass loss due to wetting-drying cycles were determined and compared.

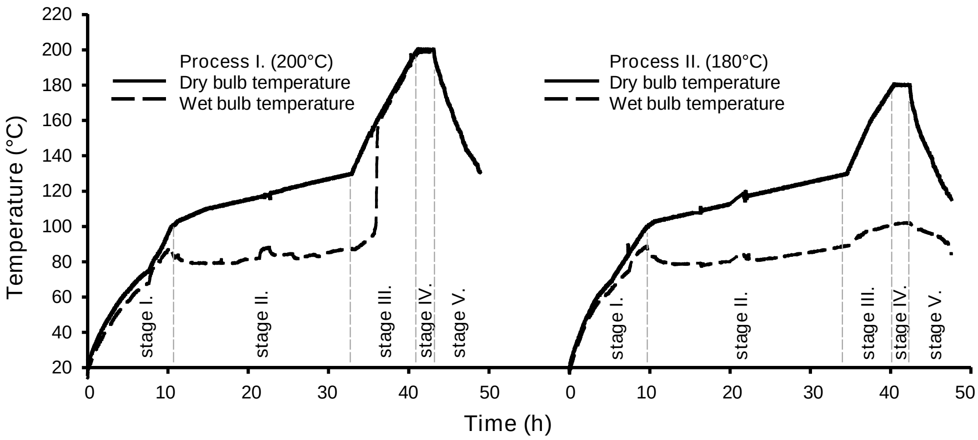

Figure 1: Thermal modification processes at 200 and 180°C, including the dry-bulb and wet-bulb temperatures and stages

As expected, higher ML was observed as more severe treatments were applied (200 °C), whereas significant differences were found for beech (6.9%) and poplar wood (10.4%) compared to spruce wood (4.5%). It is possible that the different structures and chemical compositions of hardwoods and softwoods (*i.e.*, higher hemicelluloses and extractives content in hardwoods) caused these discrepancies because extractives and hemicelluloses are susceptible to thermal decomposition. The specimen's mass tended to decrease with each additional rewetting cycle.

Additional extractives, formed via thermal decomposition, can be probably easily leached out during wetting cycles. Thermal modification positively affected the dimensional stability of all investigated species. The wood's swelling was reduced, a result attributed to hemicellulose degradation. Dimensional stability was improved by 24 to 30% following mild treatment and by 26 to 54% following more severe treatment.

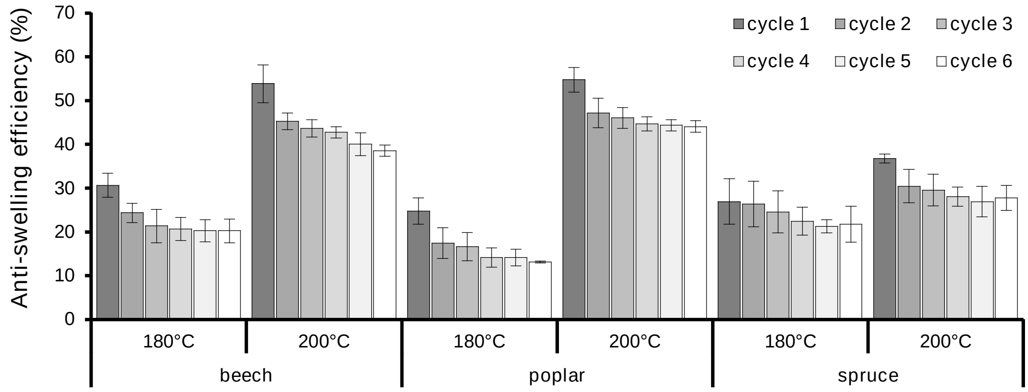

Figure 2: Thermal modification processes at 200 and 180°C, including the dry-bulb and wet-bulb temperatures and stages

The ASE values declined as the specimens were exposed to six consecutive soaking cycles. The effective dimensional stability of the thermally modified wood was reduced by 34 and 28.4% for beech, 47 and 19.6% for poplar, and 19.3 and 24.5% for spruce, respectively, after pretreatments at 180 and 200 °C, compared to the initial ASE after the first soaking cycle. The highest decrease was observed after the first soaking cycle (an average of 17%). Moreover, the ASE decreased slowly and stabilized after five cycles. This decline was because some of the newly formed extractives leached out from the wood during rewetting, making more cell wall areas accessible to water.

Conclusions:

1. Thermal modification significantly improved the dimensional stability of the wood. The radial, tangential, and volumetric swelling of modified wood decreased, resulting in 24 to 30% ASE following mild treatment (180 °C) and 36 to 54% following severe treatment (200 °C).
2. When specimens were exposed to several rewetting cycles, the initial dimensional stability of the thermally modified wood was reduced by 34 and 28.4% for beech, 47 and 19.6% for poplar, and 19.3 and 24.5% for spruce, partly attributed to the formation of leachable extractives within the thermally modified wood as a result of thermal degradation. This leaching made new areas accessible to water molecules.
3. The results should be used as a modified material indicator in such conditions because these kind of products are commonly exposed to cyclic moisture conditions during seasonal changes and the issue of dimensional stability of modified wood in these types of environments is of fundamental importance

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Sorption properties of wood bark and phloem

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Keywords: equilibrium moisture content, moisture relationships, sorption, bark, phloem

Bark is one of the biggest quantity produced by products in the sawmill industry. The high quality utilisation of this material is not solved recently. Several innovations and researches are running on improving the utilization fields of this material. An important possibility can be the usage as boards for heat, vibration or noise insulation. However, in these mentioned utilization fields it is important to know the sorption properties. This topic has only limited literature, however there is a paper dealing with North-American hardwood species (Okoh and Skaar 1980).

The main objective of this investigation was to determine the sorption properties of the bark, phloem and sapwood of different wood species. The most important wood species for the European and Hungarian wood industry were involved in this investigation. The investigated softwood species were scots pine (*Pinus sylvestris*), black pine (*Pinus nigra*), Norway spruce (*Picea abi*es), larch (*Larix decidua*) and douglas fir (*Pseudotsuga menziesii*). Ringporous hardwood species were oak (*Quercus petraea*), turkey oak (*Quercus cerris*), black locust (Ro*binia pseudoacacia*), ash (*Fraxinus excelsior*) and chestnut (*Castanea sativa*). Diffuseporous hardwood species were beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), maple (*Acer pseudoplatanus*), lime (*Tilia cordata*), poplar (*Populus × euramericana* cv. Pannonia) and birch (*Betula pendula*). Two age groups were investigated, namely young samples from forest thinnings and samples from the age of the usual final cutting of the species. Sampling was carried out during a winter period, as harvesting is made usually in this period as well. Bark phloem and sapwood was separated during sampling. Several samples were heat treated at 180°C or 200°C to determine the effect of heat treatment on these wooden parts. Desorption and adsorption curves were than determined on the untreated and heat treated samples. Beside the temperature of 20°C, relative humidity steps were following,: 20, 35, 50, 65, 80, 95%.

According to the results, sorption properties of sapwood, phloem and bark are significantly different (Fig. 1.). However, it is important to state that the differences are hardly influenced by the wood species and in case of several wood species by the age of the tree. Different changes were observed in the sorption properties of the samples as a result of heat treatment. However the tendency that the equilibrium moisture content was lower in case of heat treated samples compared to the untreated ones was the same than by wood material. This is an important advantage when the bark is used as insulation board material.

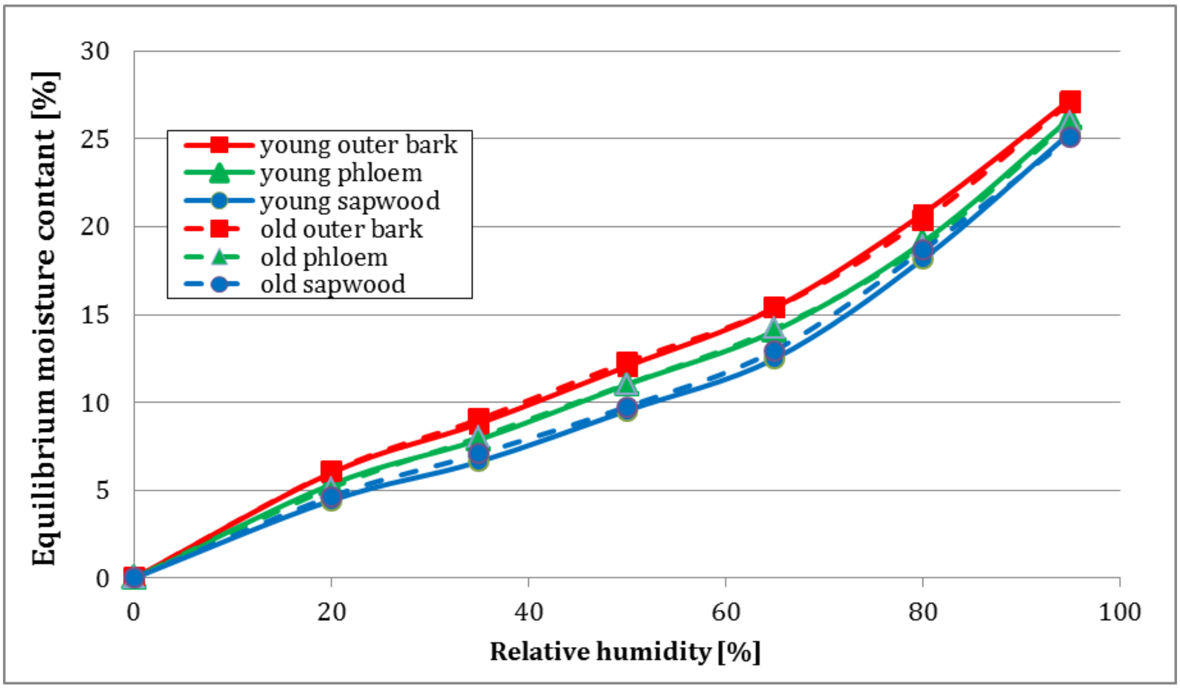

Figure 1: Desorption curves of scots pine bark, phloem and sapwood from different tree age

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The water absorption of reed for roofing depends on the lignin content of the culms

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Keywords: reed, water uptake coefficient, lignin content

A number of reed samples from different origins were investigated. An automated method adopted from Bomberg *et al.* (2004) was developed to test the uptake of water by reed samples in a time scale. As a result the capillary water uptake coefficient for reed bundles was calculated. The lignin content of different culm sections were analysed using the ADF / ADL- procedure. A section of 5 cm length was cut of the basal end of a reed bundle and in a height of 50 cm.

To provide a good stability of the reed culm a high lignin content is found in the basal sections. The lignin content decreases to the upper parts of the culm. Culms with a high diameter have a higher lignin content compared to thinner culms. Though the composition of a reed bundle with long and thick versus short and thin culms it is possible to influence the lignin content and the water absorption as well.

The water absorption is negatively correlated to the content of lignin (Fig. 1). It is assumed that the lignin blocks the capillary dynamics of water intake in function of a glue. The reed origins differ in the water uptake versus the lignin content. Some reed samples show a high content and had a low water absorption capability (red symbols: 9, 48) whereas reed origins with a lower lignin content had a much higher uptake (red symbols: 32, 45). The uptake of water is in the middle section of the culms / bundles on a higher level compared to the basal section (blue symbols in Fig. 1). The relation between the basal and the middle section is of evidence for single origins. For example has the sample 48 a low uptake in the basal and in the middle section whereas the samples 32 and 45 have in both sections a high absorption of water.

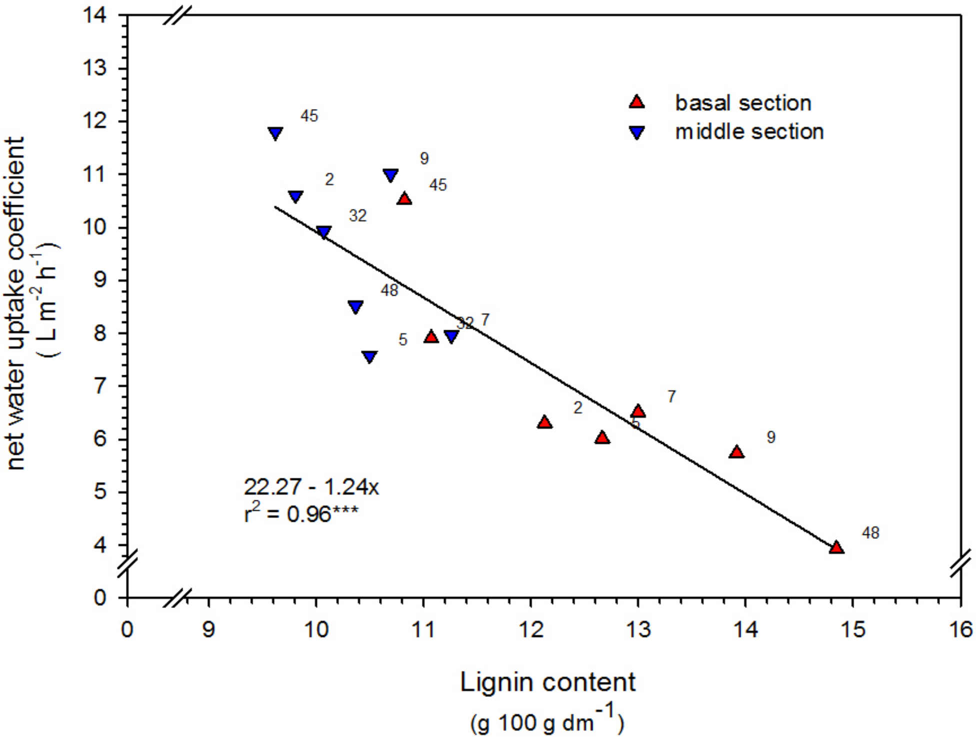

Figure 1: Regression plot between water uptake coefficient and lignin content of different reed origins (numbers)

These findings could be of importance for the longevity of reed for roofing. The water content is the condition for microbiological activity in the roof (Kirkby and Rainer 1994). The basal section is the initial port of the incoming water. A high lignin content - by a given thickness of the culms of a bundle - could preserve the water absorption over a longer period compared to lower lignin contents in the stubble. With the forthcoming degradation of the reed material over the years a high lignin content prevents the water absorption as well. Reed origins with lower lignin contents should have here problems in excluding the water from the material. The cutting high by harvest of the reed may be of interest as well. A too high cut excludes the stubble where the high lignin is located. Though a culm with low lignin is left, which is not favourable for the water uptake on the roof.

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Deterioration of thatched roofs – moisture and temperature monitoring in a cold roof museum

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Keywords: Conservation, decay, moisture data logging, service life prediction, reed (*Phragmites communis*) substitute dowel, thatched roofs

During the last decades a significant number of prematurely failing roof structures thatched with reed (*Phragmites communis*) became known (Haslam 1989, Anthony 1999). Various agents as well as changes in building practice came into consideration causing service lives of thatched roofs partly below ten years. An increased number of warm roofs with insulated attics, an increased amount of imported reed from outside Europe, newly introduced pests, disadvantageous conditions of harvesting and storage, or increased emissions from cattle-breeding farms have been discussed in this respect, but no causal relationship has been clearly proved. This study aimed therefore on investigating the moisture and temperature conditions within a reed roof structure showing severe degradation after only seven years in service (Fig.1 and 2) to obtain more information about the decay risk of reed and its potential causes.

Figure 1: Museum building with cold roof thatched with reed (*Phragmites communis*) in Bortfeld, Germany.

As for the majority of bio-based building materials moisture and temperature are key factors having an impact on their service life due to their general susceptibility to decay fungi and bacteria. The physiological needs of decay organisms are well investigated for wood and wood-based products and models to predict the service life of wooden structures do exist (Brischke and Thelandersson 2014). In this study a performance model, which had been developed for above ground decay of wood, was applied to reed. Therefore the wood moisture content of substitute dowels made from beech (*Fagus sylvatica*) wood and the temperature within the reed layer was monitored for a period of one year. The wood moisture content was determined based on electrical resistance measurements. A regression function between equilibrium moisture content EMC of wood at a given climate (T, RH) and corresponding EMC of reed was established. Therefore sorption isotherms were determined for beech wood and two different reed assortments.

Reed MC was measured at 18 different positions in the roof structure representing North and South side, different roof heights, and different depths within the reed layer. Highest moisture loads were observed on the outer part of the North roof where severe rot was observed as well as superficial growth of mosses and algae (Fig.2). However, it stayed unclear if increased MC was the reason for or the consequence of decay.

Figure 2: Decay and growth of mosses and algae on reed in the eaves on the North side of the building.

An increased MC was also found where the roof pitch turned from steep to flat. This might be due to high amounts of rain water running down the roof, water dammed up at the transition zone, or insufficient workmanship. All other roof areas did not show critical moisture conditions during the measuring period.

In this case study severe rot was observed and attributed to high moisture loads mainly in the outer reed layers. However, the reasons for prematurely failure became not evident. Further analysis of the reed material itself will provide more information about its initial quality and potential effects on the poor performance of the entire roof.

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The Estonian Open Air Museum

Triinu Poltimäe

MUSEUM'S HISTORY

The museum was founded on 22 May 1957, it started its activity the same year on 1 June. In July, the museum got a plot of 66 ha near Tallinn, on the coast of Kopli Bay, in the area of Rocca al Mare summer manor, which was established in 19 century. The museum under construction was opened for the visitors in August 1964.

On 1 January 2014, the state museum The Estonian Open Air Museum and state institution Conservation Centre Kanut joined and formed a foundation Estonian Open Air Museum Foundation. The foundation will continue as a museum that introduces rural architecture and landscape as well as a competence centre that deals with restoration, conservation and digitization.

EXPOSITION

The Estonian Open Air Museum, reminds of a village which lies in the boundaries of Tallinn. The valuable collection of Estonian vernacular architecture consists of 74 buildings from the past two hundred years. The museum continues building and more exhibit houses will be opened soon. The oldest exhibit building is the Sutlepa chapel (Fig. 1) from Noarootsi parish (1699).

As located on Estonian landscape, the farms of the museum are arranged according to old village types: farms from Western and Northern Estonia are sited in a row like in a chain village; farms from the islands stand close together around the village green of a cluster village; farms from Southern Estonia spread out here and there in a dispersed type of village. The Setu farm and Russian Old Believer’s house from the Lake Peipus, currently under construction, stand side by side by the village lane as typical to the Russian-style street-type villages.

The central position on each of the museum’s twelve farmyards is taken by the barn-dwelling, our traditional farmhouse and onetime home. This unique farmhouse has provided the Estonians with shelter for many centuries. Among the majority of barn-dwellings in the museum one can also see the modest abodes of fishermen and cotters as well as a modern dwelling from the 1930s.

Public buildings like the school, the chapel, the inn, the village shop and the fire station constitute a small village centre. The landscape is made more impressive by several mills and net sheds by the sea.

Our traditional living house – the barn-dwelling – deserves to be highlighted. It was first mentioned in writ in the 14th century. Being the northernmost tillers, the Estonian farmers needed a heated room for drying grain. When high-yield winter rye became the main bread grain 1000 years ago, the former sauna-like smoke room became too confined for drying the crops. This made the starting point for the evolution of the barn-dwelling, a unique capacious house type which is characteristic only for Estonia.

This farmhouse combines under one roof the kiln room which had a big stove and was used as the central living and grain-drying room; the spacious threshing floor used for threshing grain and housing the cattle in winter and, starting from the 17th century, additional chambers.

Barn-dwellings have local varieties. The most widespread variety is the so-called North-Estonian barn-dwelling with a kiln room higher and narrower than the threshing floor. At the Estonian Open Air Museum this type of barn-dwelling is represented by the Sassi-Jaani, Köstriaseme and Pulga farmhouses.

In the South-Estonian variety the kiln room and the threshing floor are of equal height and width; the entrance to the kiln room was usually through the threshing floor. This type of barn-dwelling is common in Southern-Estonia, Hiiumaa Island, Western-Saaremaa as well as Northern Latvia. The best example of this type is the older part of Kolga barn-dwelling, which is also the oldest farmhouse displayed at the museum (1723).

Figure 1: Sutlepa chapel from Noarootsi parish, built 1699

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