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Kebony AS
Hoffsveien 48
N-0377 Oslo,
Norway
Tel: +47 6125
Email: info@kebony.us
Web: www.kebony.com

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Furfurylated Wood Modification

Presented by: Kebony AS
Hoffsveien 48
N-0377 Oslo, Norway

Description: Wood is a versatile building material that must be protected from exposure to moisture, pests, fungi, and molds. Many tropical hardwoods are naturally durable, but unsustainable logging practices threaten their availability and the health of old-growth forests. This course discusses Furfurylated Wood Modification, one method of changing the physical characteristics of fast-growing wood to resemble tropical hardwood.

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Purpose and Learning Objectives

Purpose:

Wood is a versatile building material that must be protected from exposure to moisture, pests, fungi, and molds. Many tropical hardwoods are naturally durable, but unsustainable logging practices threaten their availability and the health of old-growth forests. This course discusses Furfurylated Wood Modification, one method of changing the physical characteristics of fast-growing wood to resemble tropical hardwood.

Learning Objectives:

At the end of this program, participants will be able to:

- describe the difference between thermal modification and chemical modification of wood.
- recall the principles of chemical modification of wood.
- describe and compare the differences between acetylated wood and furfurylated wood.
- describe the durability, appearance, dimensional stability, and strength of furfurylated wood.
- identify appropriate applications for furfurylated wood.
- describe key environmental benefits of furfurylated wood.

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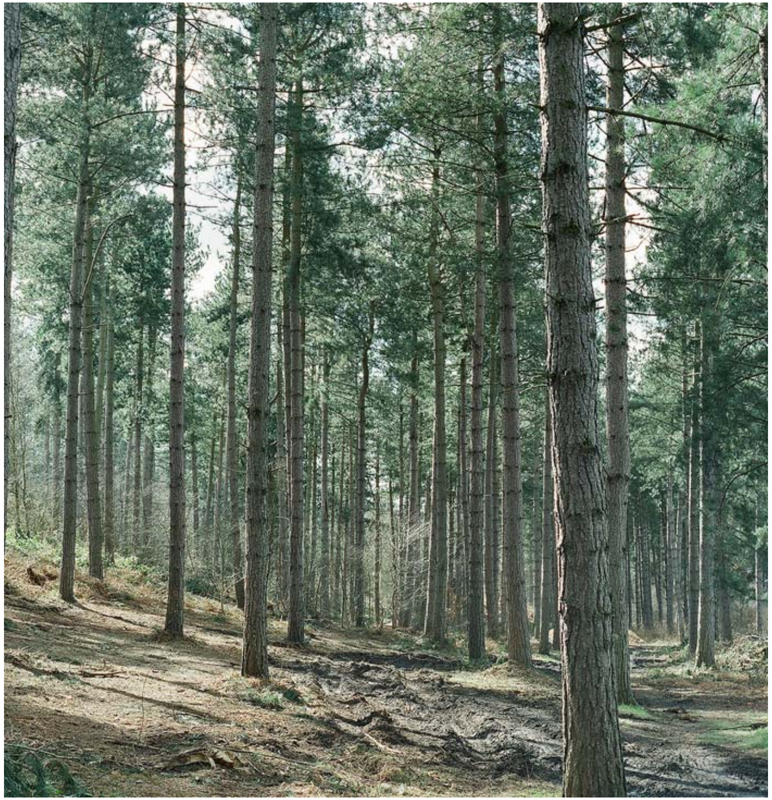


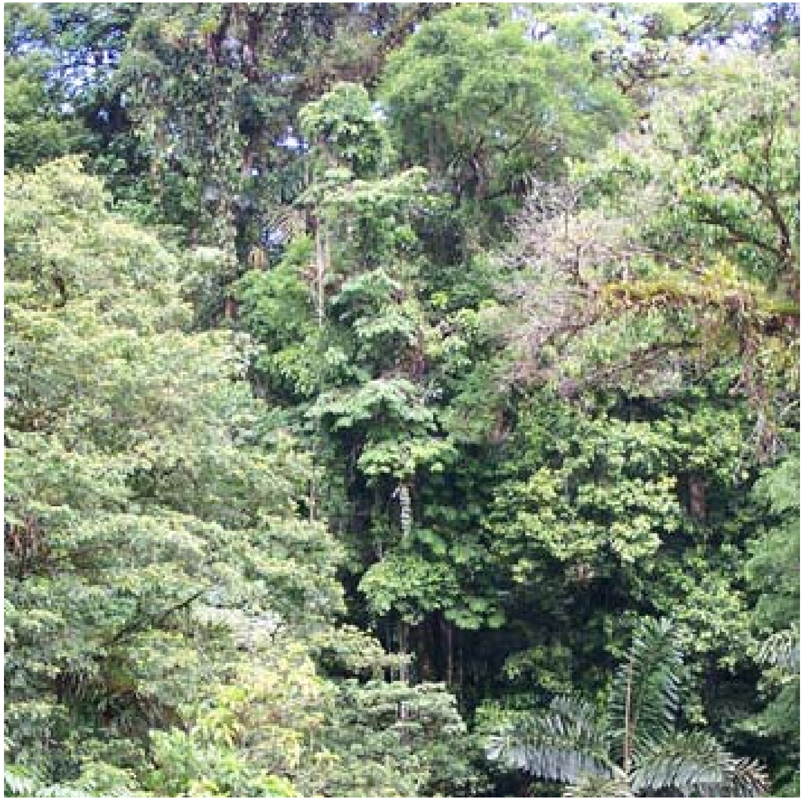
Wood Modification

Wood as a Building Material

Since the beginning of time wood has been used both for fuel and for shelter. Its strength, workability, versatility, and beauty is part of our history.

Forests form the lungs of our planet and are vital to our continued survival. Trees utilize carbon to grow and create biomass. The sequestered carbon is harbored within the wood until it's returned to the environment through decay or combustion. The harvesting of trees for building materials must be managed in a responsible way to balance this natural cycle.

The unique properties of slow-growing tropical hardwoods make them highly desirable and targets of unsustainable practices such as clear-cutting. With the latest technologies we can enhance the properties of fast-growing woods to meet our needs for performance and beauty.



The Vision for Modified Woods

Tropical hardwoods are valued for their superior strength and durability. Species such as Mahogany, Teak, and Ipe are naturally resistant to pests such as termites, fungi, and molds. Their density and strength contribute to dimensional stability and load-bearing capacity. They are commonly used in harsh conditions such as public boardwalks, site furnishings, and piers.

Tropical hardwoods are also valued for their aesthetic beauty. Their deep colors and dense grain are appealing, and show off fine joinery and detailing. Untreated tropical hardwoods weather to a pleasing gray color.

The global demand for durable hardwoods cannot be satisfied by sustainable harvesting. One solution is to use technology to create a sustainable and cost-efficient alternative product. Wood modification transforms fast-growing, sustainable woods to give them the performance of the best tropical hardwoods.

Wood Modification

Wood cells are capable of absorbing high amounts of water or water vapor. The fungi that cause rot need water to grow. Absorption of water causes the wood tissue to swell; subsequent drying causes shrinkage.

Lumber from fast-growing wood species absorb more water than dense tropical hardwoods. They are weaker, less dimensionally stable, and more susceptible to rot or pests. Biocidal preservatives can be applied to improve durability. Consumers are familiar with pressure-treated lumber, which is wood treated with chemical biocides such as chromated copper arsenate (CCA), amine copper quat (ACQ), and copper azole (CA). However, preservatives can be toxic to people and the environment.

Another way of improving performance is to create a permanent change in the wood cell wall structure. This is called *wood modification.* Dr. Callum Hill argues that modified wood should not exhibit toxicity in service, should not release toxins at the end of service, and resistance to decay should be non-toxic and non-biocidal. There are two main approaches to wood modification: *thermal* and *chemical*.

Thermal Modification

Thermally modified wood is wood modified by a controlled chemical reaction caused by applying heat in the absence of oxygen. The lack of oxygen prevents the wood from burning at high temperatures. No chemicals are used. A variety of media, such as nitrogen gas, steam, and hot oil, are used instead. Chemical changes occur in the cell walls increasing durability and slightly increasing surface hardness. However, tensile and bending strength are decreased making thermally modified wood unsuitable for load-bearing use.

The product is darker in color than the parent wood. The longer it is “cooked” the darker the color and weaker in strength making the product brittle.

Thermally modified beech
(sample on right is untreated)

Chemical Modification

Chemical wood modification impregnates wood with a substance that permanently alters the chemistry of the wood cell walls. The two main commercial processes are acetylation and furfurylation. The main advantage of chemical over thermal modification is that mechanical strength is less affected, and the resulting material is harder and denser.

The Onda restaurant, Oslo, Norway

Acetylated wood bridge, Sneek, Netherlands

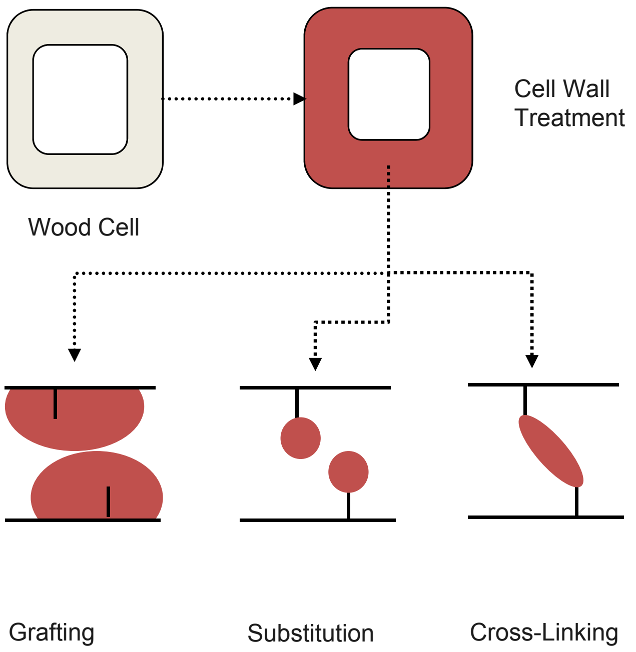
Principles of Chemical Wood Modification

Chemical modification can be based on different chemical principles.

Grafting: *in situ* solidification of modifying agents that have the ability to swell the wood cell walls by attaching to sites in the cell walls normally taken by water. The wood cell walls are locked in a swelled state and their capacity to absorb water is reduced. Furfurylated wood uses this mechanism.

Substitution: the modifying substance replaces functional groups of the wood chemistry. Most often the hydroxyl groups are substituted. This reduces water absorption capacity, and bulks the cell wall at the same time, leading to a more dimensional stable material. Acetylated wood uses this mechanism.

Crosslinking: the modifying substance has di or multifunctionality, and is able to react on a minimum of two sites of the cell-wall chemistry. This leads to crosslinked cell wall structures, and the material can obtain high dimensional stability and hardness.



Chemical Modification: Acetylated Woods

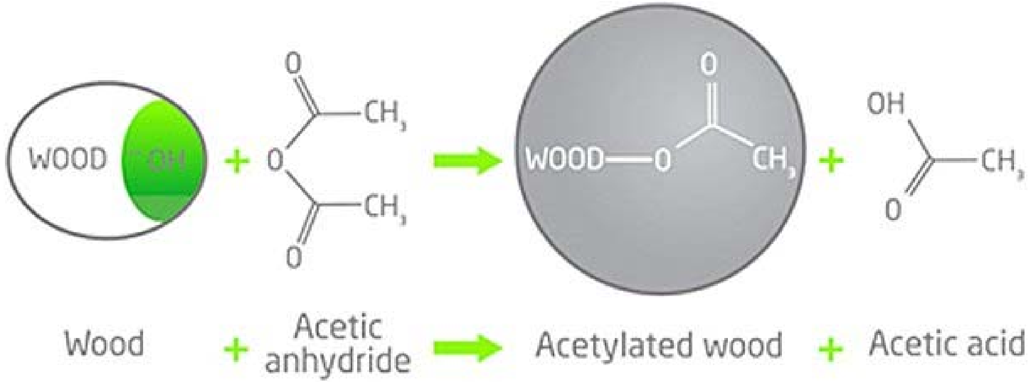
Acetylated wood is produced by treating wood with the organic liquid *acetic anhydride*.

Wood cellulose and hemi-cellulose, which in combination with lignin form the wood cell wall structures, contain an abundance of chemical groups called “free hydroxyls.” Free hydroxyl groups readily absorb and release water according to changes in climatic conditions. This is the main reason why cellulose, and therefore wood, swells and shrinks.

The impregnation of acetic anhydride causes a chemical reaction between the free hydroxyl sites and acetic anhydride that effectively changes the free hydroxyls within the wood into *acetyl* groups. The acetyl groups do not attract water and therefore hinder the absorption of water in the cell walls.

Acetylated wood characteristics:

- Enhanced dimensional stability
- Improved resistance to decay
- Improved hardness
- Same bending strength as parent wood
- Improved thermal performance
- Similar color to parent wood that weathers to silver-gray



Chemical Modification: Furfurylated Wood

Furfurylated wood is produced by treating wood with *furfuryl alcohol*, a bio-waste derived from the by-products of agricultural crops, mainly sugar and corn.

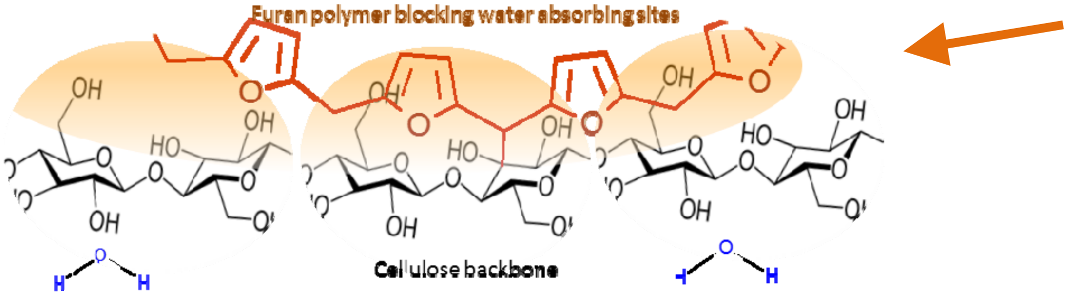
The parent wood is impregnated with furfuryl alcohol under moderate pressure. Upon the action of organic catalysts and moderate heat, the absorbed furfuryl alcohol will form an inert solid inside the wood. This chemical process is irreversible, and leaves the wood tissue permanently in a partially swelled state. At the same time, the water-absorbing capacity of the wood is reduced. The results of this permanent "bulking" of the wood tissue are increased hardness, dimensional stability, and durability.

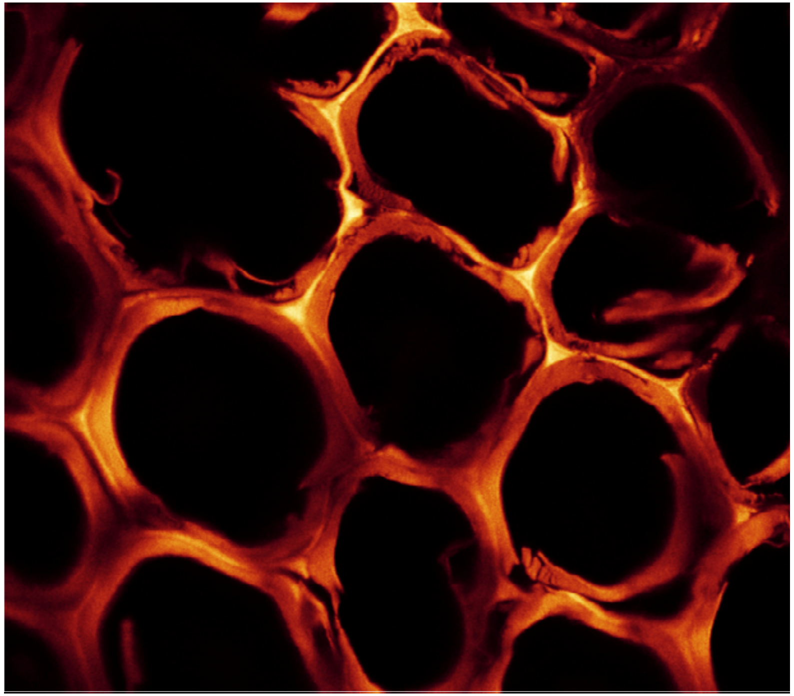
Furfurylated wood characteristics:

- Enhanced dimensional stability
- Improved resistance to decay
- Improved hardness
- Improved stiffness
- A darker color than the parent wood that weathers to silver-gray

Furfurylation at the Wood Cell Level

In the furfurylation process, furfuryl alcohol is impregnated into the lumber. The furfuryl alcohol will occupy molecular sites otherwise taken by absorbed water in the wood cell wall structure. *Polymerisation*—the combination of furfuryl alcohol molecules into long chains and networks—creates solid *furan polymers*. These polymers are “grafted” to the wood cell walls. They are very stable and will not degrade or leach out of the wood.





Cross section of Radiata Pine with cell walls containing furan polymer; image through fluorescence microscopy (L. Garbrecht Thygesen, RVAU, Copenhagen, 2006).

Comparing Modification Methods

Parameter	Furfurylated Wood	Thermal Wood	Acetylated Wood
Modification principle	Furan polymer grafting	Heat treatment	Acetylation
Appearance	Brown, graying on weathering	Brown, graying on weathering	Pale, good color stability on weathering but vulnerable to staining fungi
Strength parameters	Improved stiffness	Reduced bending strength	Bending strength unchanged from parent wood
Hardness	***	*	**
Dimensional stability	**	**	***
Fastener holding strength	***	*	**
Durability / decay resistance	***	**	***



Furfurylated Wood Products

History of Furfurylated Wood Production

The principles of forming furan polymers were discovered in the 1920s. Early attempts at wood furfurylation and research did not result in a product viable at an industrial scale. The earliest furfurylated wood was a dense, chemically resistant product used for laboratory countertops and knife handles.

Research in the 1990s, led by Dr. Mark Schneider of the University of New Brunswick, Canada, led to a patented, industrial-scale process. The goal was to create a high-performance wood with all the best characteristics of tropical hardwoods using fast-growing sustainable woods. The result was a product suitable for internal, external, decorative, and load-bearing applications.

In 2003, a pilot plant was built in Norway, followed by a full-scale industrial facility in 2009. By 2011, furfurylated wood was being exported to several countries, including France, Germany, and the UK. In 2012, the KREOD pavilion at the London Olympic Games drew international media attention to furfurylated wood. By 2014, furfurylated wood was available in 22 countries including the Unites States. A second plant is scheduled to open in Belgium in 2017. A third is planned for the United States, which will process indigenous species.

Furfurylation plant, Skien, Norway

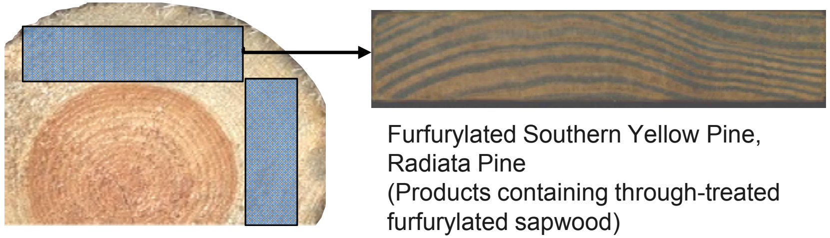
KREOD Pavilion, London

Sapwood Produces a Homogenous Material

In softwoods, only the sapwood can be impregnated with liquids. Clear sapwood boards produce homogeneous furfurylated products with the best durability—*clear products*.

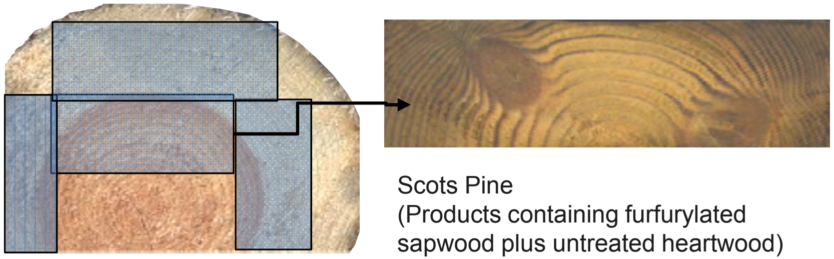
Pine species where the heartwood has a degree of natural durability are used for products consisting of both furfurylated sapwood and untreated heartwood. These *character products* are frequently used in above-ground applications as sustainable alternatives to preservative-treated lumber. Durability of the finished product will depend on the proportion of heartwood, and its natural resistance to decay. Due to the heartwood's density and high resin content, its portion of the board is very difficult to penetrate with liquids and consequently remains un-treated.

Other fast-growing woods, such as Maple, can also be furfurylated. However, Pine is currently the standard source wood.



Furfurylated Southern Yellow Pine, Radiata Pine
(Products containing through-treated furfurylated sapwood)

Clear Products

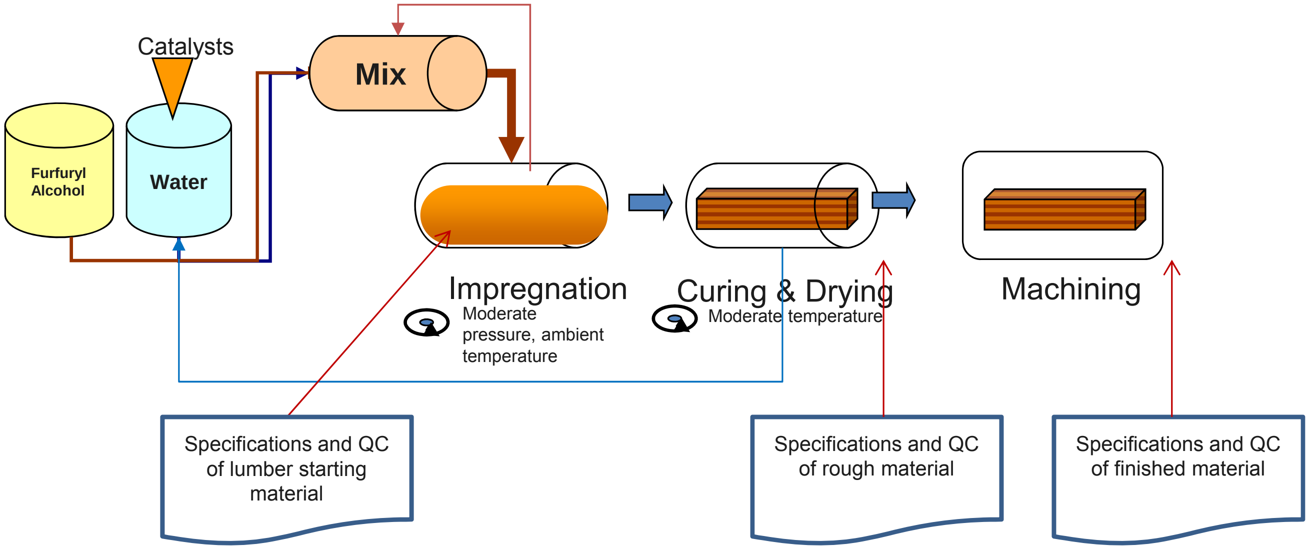


Scots Pine
(Products containing furfurylated sapwood plus untreated heartwood)

Character Products

Quality Control

The quality of each batch of lumber is controlled from receipt of raw materials to the final product. Source wood is graded with scanners prior to treatment, and hand-graded after treatment. Rejected material is cut down or re-profiled into another product.



Impregnated charge to be fed into drier

Quality control scanner

Appearance

Furfurylated wood technology changes the appearance of the parent wood. The induced dark brown color is an inherent property of the furfurylation chemistry.

Clear grades have no knots or defects, and are cut from pure sapwood. The finished color is even and dark brown. Character grades contain some knots and color variation, which are accentuated by modification.

As with any natural wood product, the presence of sun and rain will alter the color into a silver-gray patina. The deeper color and patination make furfurylated products similar in appearance to new and weathered tropical hardwoods.

Untreated softwood

New furfurylated product

Weathered furfurylated product

Testing and Performance

Product Testing

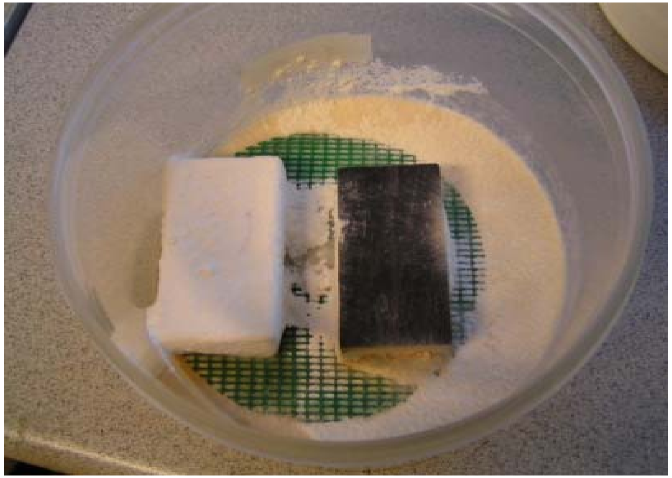
Years of third-party testing in the laboratory and in the field have documented furfurylated wood's excellent performance in:

- Durability against fungi and insects
- Weathering, coating, and gluing
- Environmental impact: smoke gas testing, fire testing, leaching, eco-toxicity, emissions
- Physical/mechanical properties
- Human health and chemical risk assessment

Product Performance: Decay-Resistant

Furfurylated clear Southern Yellow Pine (SYP) and clear Radiata Pine have a Class 1 rating per European standard EN 350—“Durability of Wood and Wood-based Products – Natural Durability of Solid Wood.” They are as resistant to wood-decaying fungi (rot) as Ipe and Teak. Fungi appear not to recognize furfurylated wood as a food, nor are they able to use it as a nutrient.

AWPA E10 “Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Culture”



EN113 “Wood preservatives. Test method for determining the protective effectiveness against wood destroying basidiomycetes. Determination of the toxic values”

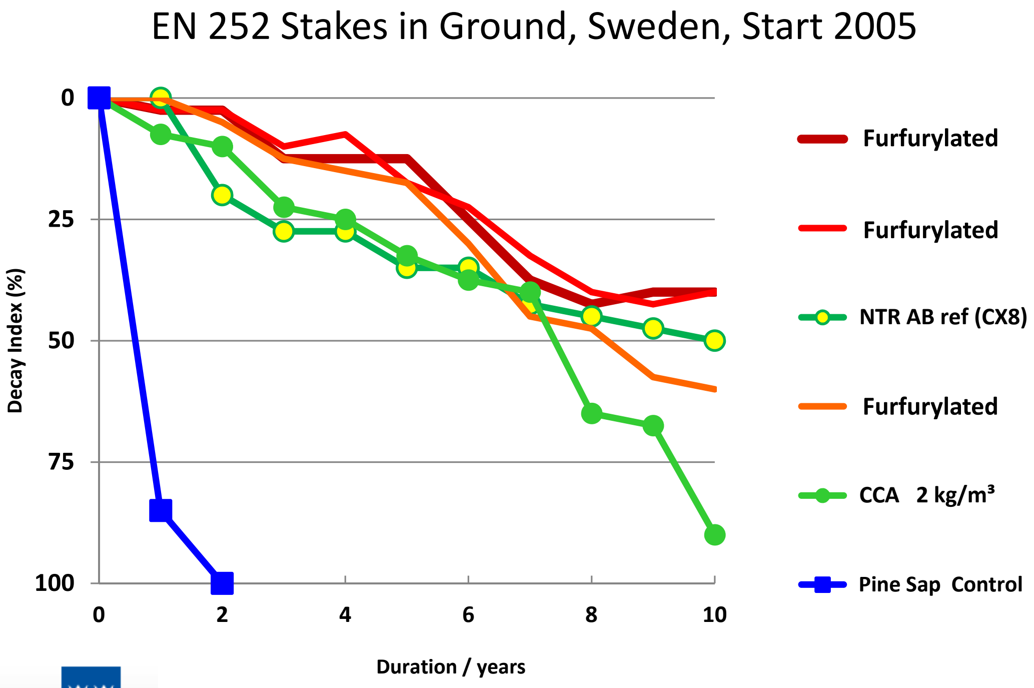
EN252 “Field test method for determining the relative protective effectiveness of a wood preservative in ground contact”

Product Performance – Decay Resistant

Wood will decay even above ground, and the main volume of the preservative treated wood is intended for above-ground applications.

This figure shows that furfurylated pine sapwood performs on par with or better than CCA or Cu preserved pine in in-ground tests.

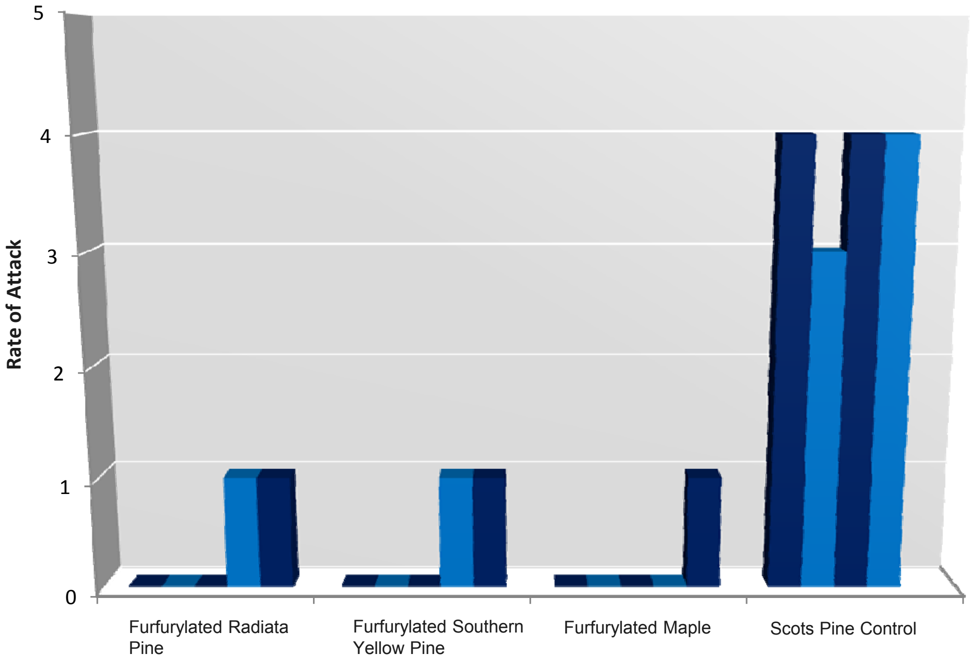
Although decay in ground is much faster than above ground, such tests give a good *relative* performance comparison between products, even for above ground use



Product Performance: Termite-Resistant

Laboratory and field testing proves that furfurylated wood is resistant to termites.

This chart diagrams the results of laboratory tests conducted by AIDIMA (2011). Samples were visually graded on a scale of 0–4, after 8 weeks exposure to the termite species *Reticulitermes spp*.



Furfurylated wood showed strong termite resistance relative to an unmodified control sample.

Product Performance: Hardness and Strength

When tested to the Brinell Hardness Test (per EN 1534), furfurylated clear Southern Yellow Pine is more resistant to indentation than Ipe, Teak, or Oak.

Furfurylation increases the stiffness of the parent wood by 10–20% and hardness by 30–50%. Bending strength remains unchanged.

Wood Species	Durability 1=best EN 350	Hardness Brinell N/mm^2 EN 1534
Furfurylated Maple**	1	59
Ipê	1	53
Furfurylated Souther Yellow Pine	1	54
Furfurylated Radiata Pine	1	41
Teak	1	34
Thermo Ash	1-2	30
Furfurylated Scots Pine	1-2*	20-30
Bangkirai	2	63
Oak	2	33
Thermo Pine	2	16
Siberian Larch	2-3	17
Scots Pine	3-4	17
Maple	5	37

*) Sapwood **) NOT Standard product

Product Performance: Moisture Content and Dimensional Stability

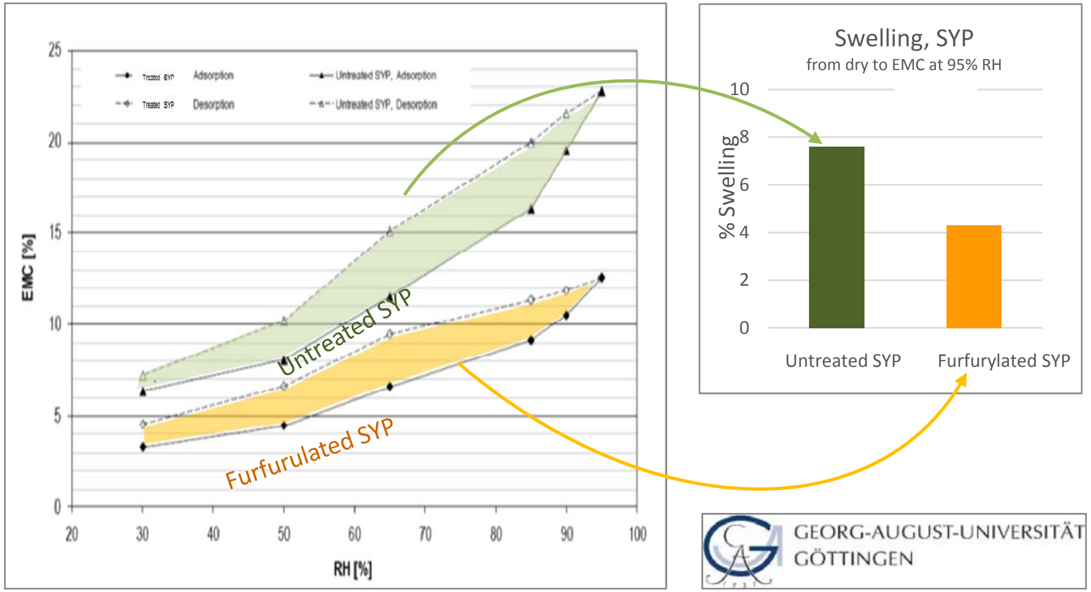
Furfurylated wood has a lower *Equilibrium Moisture Content* (EMC) than untreated lumber; in other words, it has a lower tendency to absorb moisture.

The EMC value is the amount of moisture in the wood when the wood has reached equilibrium with the ambient humidity levels and ceases to absorb more water. The lower the EMC, the greater the dimensional stability of the wood. Lower moisture content also means a lower susceptibility to rot.

The green area on the left-hand graph shows the EMC measured on untreated Southern Yellow Pine (SYP). The yellow area shows the EMC of furfurylated SYP.

The right-hand graph shows the difference in measured swelling between untreated and furfurylated SYP.

Furfurylation decreases the shrinking and swelling of the parent wood by about 50%.



GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN

Sustainability: Certification

All actors in the supply chain can be certified to widely accepted sustainability standards such as the Forest Stewardship Council (FSC) or the Program for the Endorsement of Forest Certification (PEFC).

Both organizations are international and uphold mostly equivalent standards. The North American Sustainable Forestry Initiative (SFI) label is endorsed by PEFC.

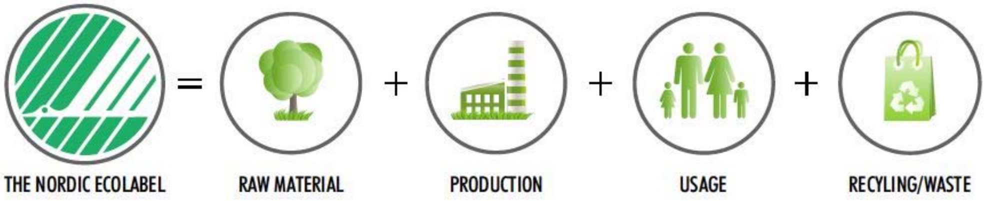
Currently more than 70 percent of the raw materials used for furfurylation comes from FSC- or PEFC-certified forests and mills. Processed woods are from sustainable sources and controlled by the EU Timber Regulation (EUTR).

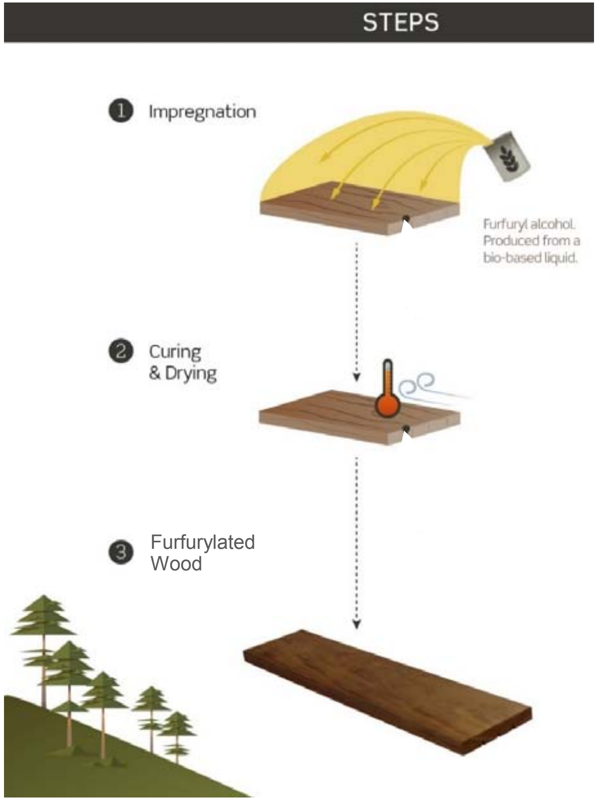
Certification serves to ensure biodiversity and the preservation of habitats and biotopes typical of forests. Certification also safeguards the rights of people working in forests and ensures that forests can continue to be used for recreational purposes.

Sustainable Production Process

Furfurylated wood has achieved the Nordic Swan Ecolabel. This certification requires compliance with strict regulation of logging, chemical use and manufacturing process. The use of biocides to achieve durability is prohibited.

The Nordic Swan Ecolabel is the official Ecolabel of the Nordic countries, a voluntary and positive practical tool for consumers to help them actively choose environmentally sound products. The Nordic Swan Ecolabel is an ISO 14024 type 1 Ecolabelling system and is a third-party controlled certification.





Sustainability: Non-Toxic

Furfurylated products are a good choice for schools and kindergartens. The strict criteria for residual chemicals demanded by the Nordic Ecolabel—the Swan—ensure that the products are recognized as non-toxic. The bio-based polymer in the furfurylated wood is in itself inert, and consequently not toxic or eco-toxic.

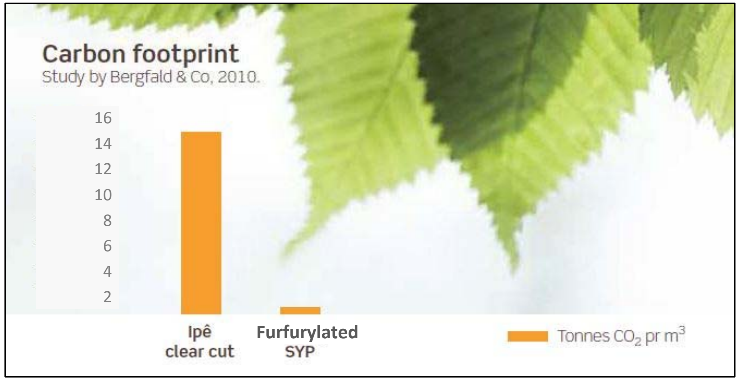
Research concluded that furfurylated wood in contact with water or soil did not leach toxins harmful to aquatic or terrestrial organisms[1]. The same studies found that burning furfurylated wood did not release any VOCs or combustion products beyond that of untreated wood. Furfurylated wood can be recycled or disposed of like normal, untreated wood.

[1] Lande, Westin, and Schneider (2004)

Sustainability: Carbon Footprint

A 2010 study calculated the carbon footprint for clear-felled Brazilian Ipê, including treatment and transportation to Northern Europe, to be in the range from 7,500 to15,000 kg CO_2 per cubic meter lumber. The majority of Ipê sold is from clear-felled sources. Calculations are based on LULUCF recommendations developed by the IPCC[1].

The carbon footprint of furfurylated clear Southern Yellow Pine (SYP) delivered in Western Europe is approximately 660 kg CO_2 per cubic meter, calculated in recently developed Environmental Product Declaration[2]. SYP is grown in sustainably managed forests in the US that produce a net gain in biomass. The carbon footprint is calculated for Cradle-to-Grave (including energy recovery) life cycle for the product, representing the raw materials phase, processing, transport, use, waste disposal, and energy recovery.



[1] (IPCC, 2003, Good Practice Guidance for Land Use, Chapter 3: Land-Use Change and Forestry), [2] http://epd-norge.no/heltreprodukter/kebony-clear-syp-article966-320.html

Installation and Maintenance

Finishing

Furfurylated boards have a deep brown color that will naturally form a silver-gray patina over time. Checking, or small surface cracks, will also occur. The speed of this process depends on exposure conditions and type of application. Normally it will happen gradually over a few months, but intense exposure to sunlight and rain will accelerate the process.

The change in appearance has no effect on resistance to decay or other technical properties. The original color can be maintained using UV protection oils. Furfurylated wood may also be painted, stained, or surface coated. Wood oils or water-based acrylic paints are recommended. High dimensional stability gives good coating adhesion and durability.

Clear grades may be sanded, brushed, planed, and profiled without reducing durability. Character grades are not intended for further machining of the surface.

New

Weathered

Installation

Reactions to Metals:

- Furfurylated wood substrate is slightly acidic. Acid-proof fasteners, such as stainless steel fasteners are recommended to avoid staining. Iron, carbon steel, or galvanized steel (e.g. i fasteners) may stain the wood by contact with water run-off on the surfaces.
- Run-off from furfurylated wood may cause black surface staining on zinc, or induce shiny patches on copper.
- Aluminum will not react to furfurylated wood.

Adhesives:

- Furfurylated wood can be glued and laminated with several glue types (e.g., PUR, EPI, PRF, epoxy).

Machining:

- Machine the product as typical hardwoods. (Clear grade, homogeneous products)

Glue-ability

SHR, an independent timber research and testing institute located in the Netherlands, tested the glue-ability of furfurylated wood as part of the EU funded Ecobinders project. Untreated and treated wood were evaluated to EN 204 "Classification of thermoplastic wood adhesives for non-structural applications," using two different D4 wood adhesives. Five different wood species, each treated with two levels of furfurylation, were tested. The two treatment levels represent low and normal strengths of furfurylation. All combinations complied to EN 204; however, researchers noted that:

- Shear strength of Aspen, Radiata Pine, and SYP was reduced by the treatment, and this reduction increases with increased treatment level.
- Shear strength of clear Beech was unchanged by treatment.
- Shear strength of Maple was reduced by low treatment, but was increased by the normal treatment.

Researchers tested wood failure and adhesive failure in treated wood and untreated wood, concluding that:

- In dry conditions, there is no clear impact on adhesive failure by treatment.
- In wet conditions, glue-ability is generally negatively influenced by the treatment. This negative impact was most evident in wood failure.

Installation

Fastening:

- Self-drilling screw are recommended. If using regular screws, predrill the holes.
- Always predrill holes when fastening at the edge of a board, to avoid cracking.

Cutting:

- Cut edges on clear grades do not require special treatment.
- Cut edges on character grades must be painted with anti parasite/fungal agent.

Decking Support:

- Maximum joist spacing is 20″ to 24″ (50–60 cm) on center, depending on the specified product.

Maintenance

Furfurylated wood products are hard and dense.

Maintenance consists of regular cleaning with a soft brush and household detergents. The use of pressure washers are not recommended unless at a low pressure.

The life expectance will be over 30 years if properly maintained, and most manufacturers of furfurylated products will give a 30-year warranty.

Applications

Windows

Furfurylated wood is a sustainable alternative to tropical hardwood window frames and is approved by the German Association of Windows and Facades (VFF) for use in windows. Several European window manufacturers supply furfurylated wood units in their offerings. Furfurylated wood can be worked the same way as any hardwood in the manufacture of the window casings. EPI, MUF, and PRF glues have been proven to work well.

Cladding

Furfurylated wood is a durable choice for cladding, whether left to weather naturally or finished with an oil or coating. Standard profiles are available from manufacturers, or rough sawn product may be ordered for custom milling.

Roofing

Standard roofing profiles are available with a water channel on the lower lip. Furfurylated wood is suitable for roofing cladding; however, a waterproof membrane is still required.

Decking

Furfurylated wood is as durable as the best tropical hardwoods, making them a suitable alternative in areas of high foot traffic or moisture. Larger boardwalk dimensions are a standard product and readily available in both clear and character grades.

Decking

Clear grade furfurylated wood is available in the finished dimensions as shown, but is also available as rough sawn product for in-house machining.

Character grade decking is only supplied as a finished product and is unsuitable for further machining, due to the heartwood content. Heartwood exposed by machining will reduce product durability.

Decking may be attached using face or concealed fixing systems.

Decking

Furfurylated wood decking can be machined into any profile to accommodate face fixing, side insertion, or concealed attachment.

Furfurylated wood is dimensionally stable; however, it is a natural product and will shrink and swell due to the relative humidity. Consult the manufacturer to determine appropriate board spacing.

★ Please remember the **exam password CHARACTER**. You will be required to enter in order to proceed with the online examination.

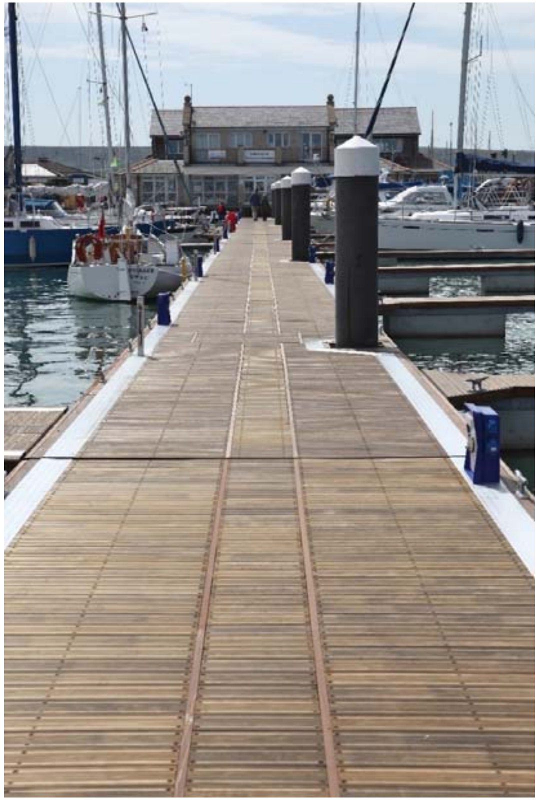
Street Furniture

Furfurylated wood is becoming popular for street furniture applications as it has good dimensional stability, excellent durability, and premium aesthetic appeal.

Unfinished furfurylated wood will weather to a silver-gray patina like tropical hardwoods, with no loss of durability. Consult the manufacturer for recommended finishes if a specific color is desired.

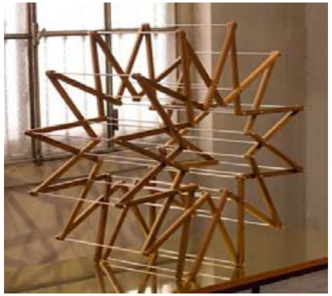
Marine

Furfurylated wood is a proven performer in harsh marine environments. Piers, harbors, boardwalks, and even boat decks are suitable applications.



Other Applications

Designers use furfurylated wood anywhere tropical hardwoods might be used, such as household objects, furniture, or even musical instruments. The dimensional stability, durability and workability of furfurylated wood make it the ideal choice for a wide variety of applications.



The Demand for Furfurylated Wood

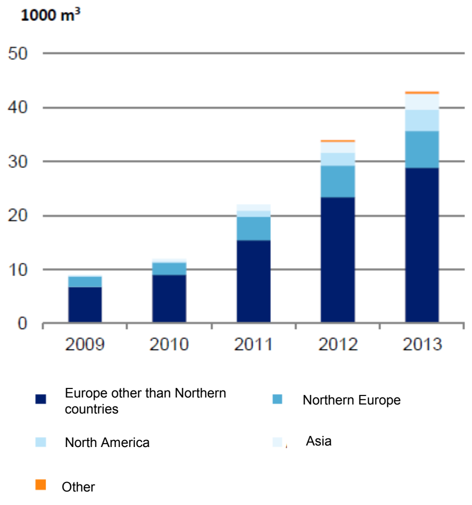
Sustainable materials are becoming more widely available, and demands for high-performance wood continues to grow. As a result, global demand for modified woods is increasing.

North American demand is expected to grow even faster as the leading European modified wood manufacturers become competitive with Tropical Hardwoods, WPC, and traditional impregnated woods.

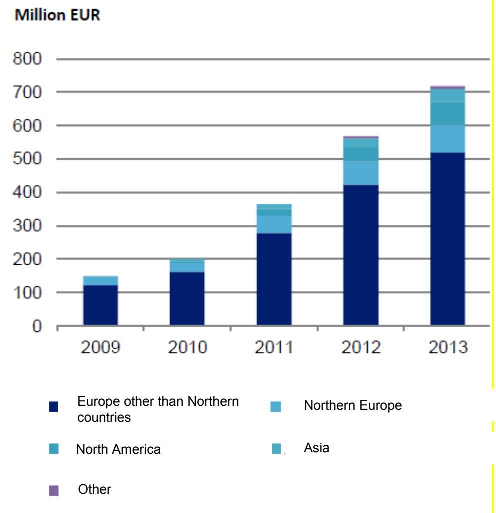
Currently over 60% of the demand for modified woods is met by two major European companies. Furfurylated wood represents approximately 35% of all the modified wood demand.

Already we have seen the two largest suppliers of modified woods hitting capacity and expanding production to satisfy demand.

Global Market Demand for Modified Woods by Volume (m^3)



Global Market Demand for Modified Woods by Sales (Euros)



Case Studies

Case Studies

The Inn at Harbor Shores
St. Joseph, Michigan

Furfurylated wood was selected as decking for 68 seasonal docks, based on its proven durability.

The Floating Science Barge
Miami, Florida

A floating public environmental education center utilized furfurylated wood for its durable, low-maintenance decking, furniture, and millwork.

Case Studies

The Rainscreen House
Washington, DC

The architects specified dimensionally stable furfurylated wood cladding to achieve close tolerance detailing in the renovation and addition to this 1920s house. The cladding is uncoated, and will eventually develop a gray patina.

Hunter's Point South Park
Queen's, New York

This waterfront park includes a green space, beach, pavilion and a native plant garden planted over decommissioned railway tracks. Furfurylated wood was chosen for the elevated boardwalk and site furniture.

Case Studies

Tommy Bahama Restaurant & Bar
Waikiki, Hawaii

Sustainability was an important concern of the owner, and furfurylated wood was used throughout the three-story, 15,000 sq ft restaurant and rooftop lounge. The spiral staircase forms a stunning focal point and showcases the rich, natural aesthetic of the furfurylated product.

Martial Cottle Park
San Jose, California

The architects specified furfurylated wood cladding, fencing, and sunshades for three new LEED Silver buildings in this public park. Durability in the harsh climate and toxin-free qualities were key factors in wood selection.

Summary and Resources

Summary

Wood is a material inherently vulnerable to decay. The strongest and most durable woods are tropical hardwoods, which are in limited supply and in many cases unsustainably harvested. Clear-cutting of slow-growing species endangers product supply, and damages the rainforests' ability to sequester carbon.

One solution is to treat fast-growing woods to improve their performance. A strategy is to modify wood at the cellular level with heat or chemical processes. The two main chemical modification processes are acetylation and furfurylation. Both methods produce a wood product that is as durable against decay at the same level or better as tropical hardwoods. Furfurylated wood has a similar appearance to tropical hardwoods, having a deep color that weathers to gray.

Furfurylated wood is made mostly from sapwood of Southern Yellow Pine or Radiata Pine. It can be used for decking, cladding, roofing, window frames, and other applications. It is non-toxic and can be disposed of at the end of service like ordinary untreated wood.

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Conclusion

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