Applications and Opportunities with European Wood Modification

Holger Militz

Professor and Head Wood Biology and Wood Products

Georg-August University Göttingen

Germany

Own research background

- 1987 – 2000: TNO/ SHR Timber Research, The Netherlands
  - Heat treatment technology (PLATO)
  - Acetylation technology (Accoya)

- 2000 – today: University Göttingen
  - Belmadur
  - Silicones/ Silanes
  - Furfurylation (Kebony)
  - Waxes/ oils
  - Melamines/ phenols

Content of presentation

Wood modification

- Why?
- How (principles)
- Processes and material
- Products and markets
- Challenges

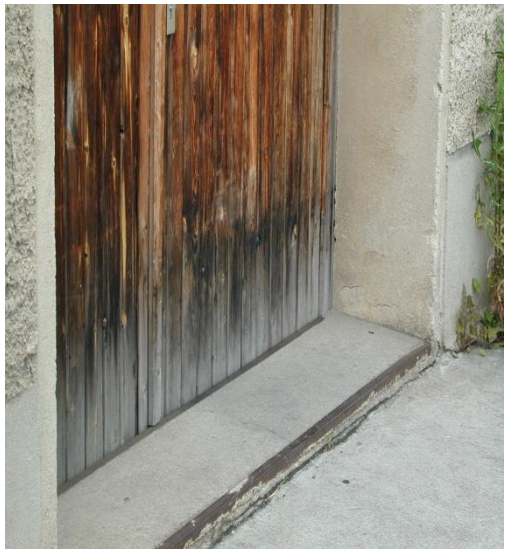
Wood: material of the future

- Ecological
- Sustainable
- Renewable
- Esthetical
- Traditional and modern

Wood: material of the future

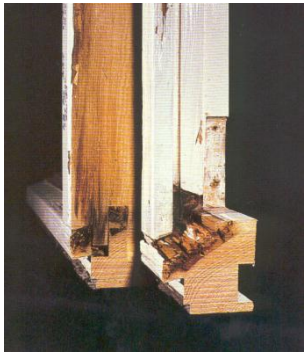
- Energy efficient
- End-of-life: energy

Wood: material of the future?



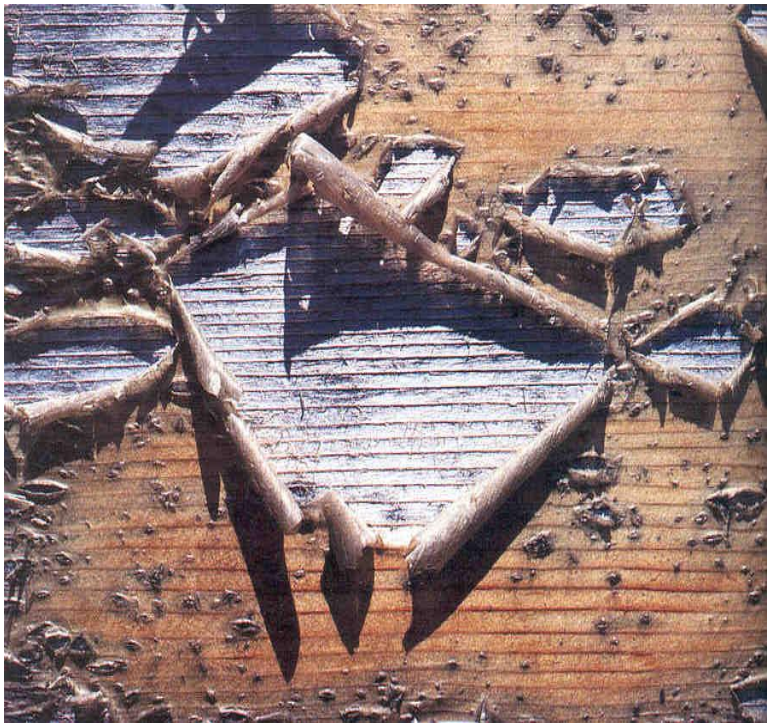
Weak points:

- Moisture sensitive
- UV-stability
- Dimensional movements
- Resistance against fungi
- Soft surface



Wood: material of the future?

Maintenance problems due to dimensional instability and UV instability!

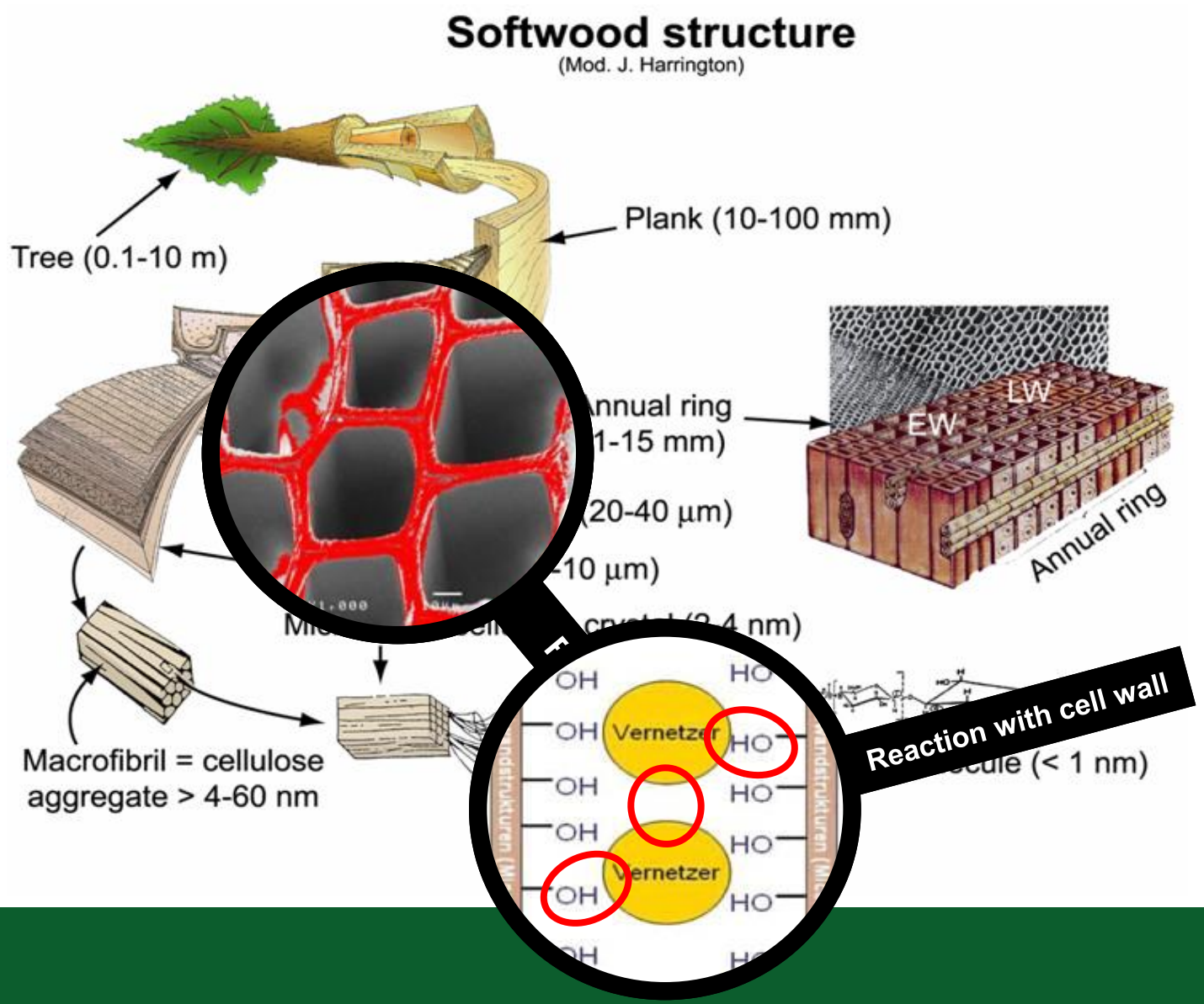


Solutions/ Alternatives?

- Use wood with high natural quality (as many tropical hardwoods)
  - Availability (mid term, long term)
  - Sustainability
- Use of wood preservatives
  - Toxicity issues
  - New biocides with low impact
  - Only durability item solved
- Use of new technologies for wood treatment
  - Wood modification!

What is „wood modification“?

What is wood modification?



Wood modification technology

- Heat treatment
- Acetylation (Accoya)
- DMDHEU (Belmadur)
- Furfurylation (Kebony)
- Silicone/Silane
- Oil / Wax/ Parafins

On the market production capacity

- Melamine resin

Production capacity built

- Chitosan/
- Extractives etc.

??

Challenges: “from idea to commercial applications”

(PhD defense Stig Lande 2008/ ECWM 2009 Militz, Lande)

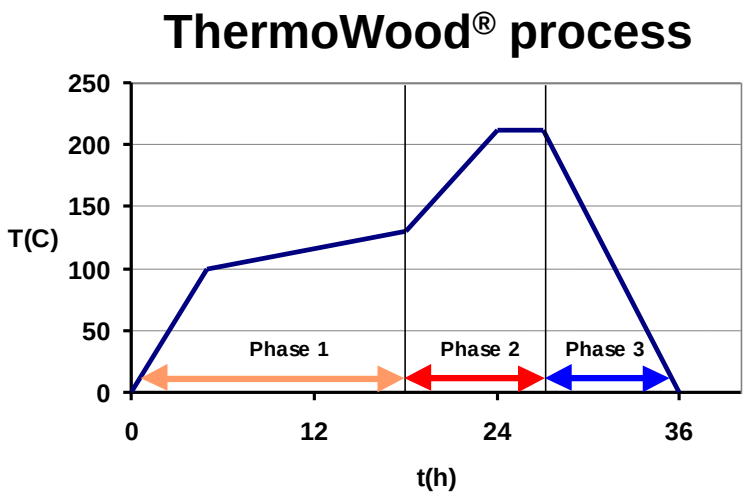
- Raw materials
- Chemical reactions
- Process parameters

- Material interactions
- Quality control
- Market requirements

- Market
- Economy
- Intellectual property

Thermo treatment (TMT, Thermowood)

- no chemicals
- temperature 180° C to 220° C
- many wood species used
- difference between producers:
  -technology used



Photos: Plato process

Status quo of production (2010): EUWID
(Europäischer Wirtschaftsdienst)

- Production in **Finland,** Germany, France, Croatia, Austria, Switzerland, Netherlands, Turkey, Sweden, Estonia

- Total capacity approx. 200.000 m^3/ year
- Finland approx. 100.000 m^3/ year

- Largest plants: 30.000 m^3/ year
- Smallest plants: 1.000 m^3/ year

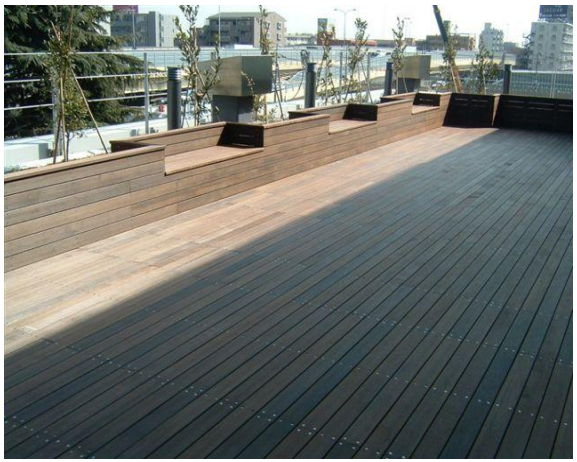
- New plants planned/ under construction

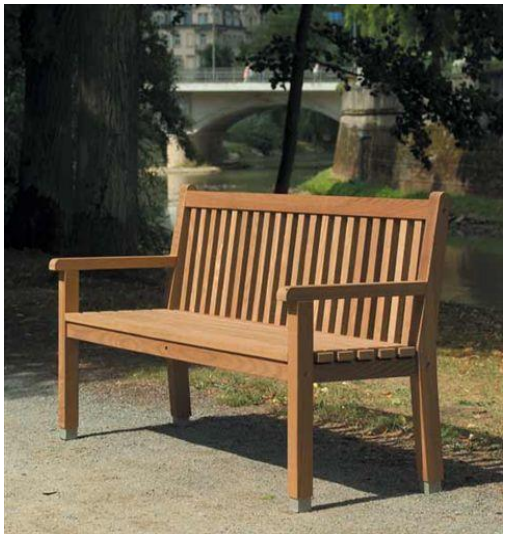
Use class 3 (EN 335)

(Photos by Thermowood Association, Finland)

Use class 3 (EN 335)

(Photos by Mitteramskogler/ Austria)





Use class 1-2 (EN 335)

(Photos by Mitteramskogler/ Austria)

Use class 1-2 (EN 335)

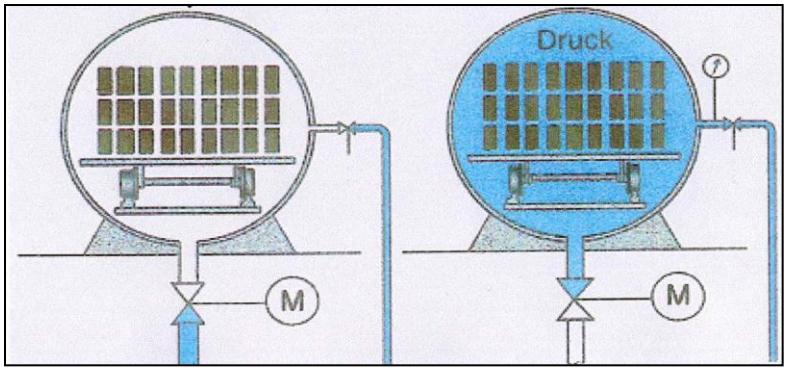
(Photos by Mitteramskogler/ Austria)

Modification technology based on liquids

- **Belmadur® Technology**
  - (DMDHEU)
- **Kebony® Technology**
  - (Furfurylation)
- **Accoya® Titanwood**
  - (Acetylation)
- **Silanes/ Silicones**

Modification based on liquids

- liquid, catalyst
- vacuum-pressure impregnation
- drying and reaction
- drying temp: above 100 ^{0}C

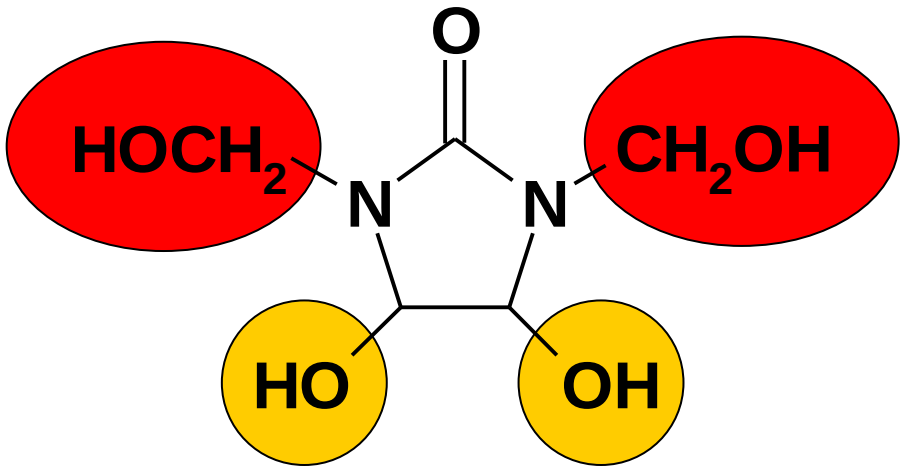


Materials and methods

- NMM-BS impregnation of beech

- High temperature curing

Belmadur® Technology



DMDHEU

(1,3-dimethylol-4,5-dihydroxyethylene urea)

Originally:

- textile modification
- (Easy Care Cotton)

BASF
The Chemical Company

Cross-linking cellulose molecules

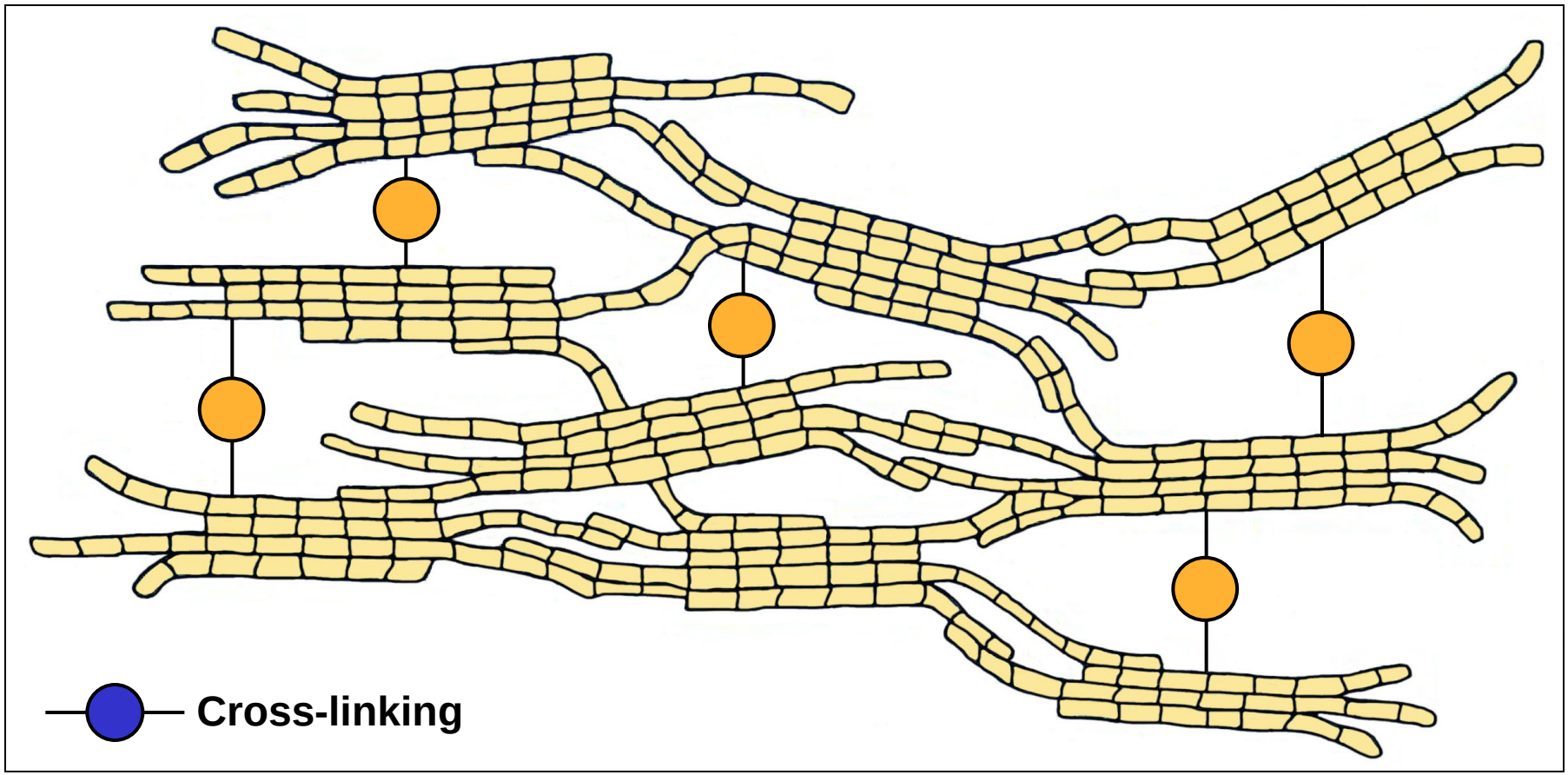
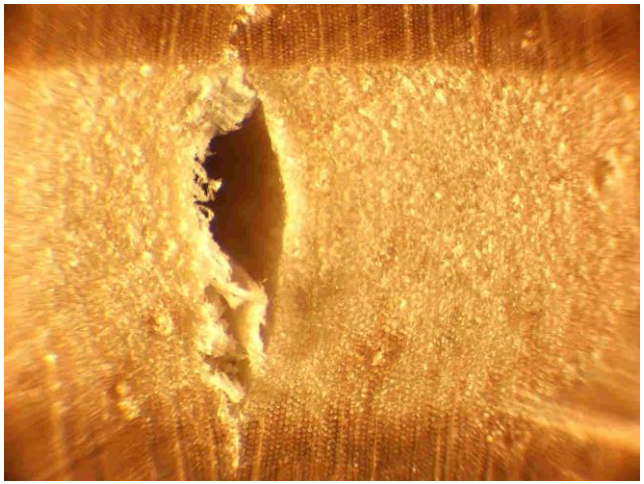


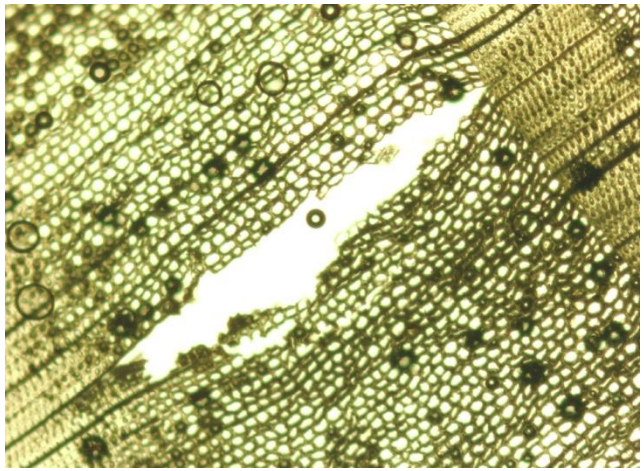
Foto: BASF

Process development of the recent years

- Solid wood
- Veneers
- Wood composites
  - Particles
  - Fibres
- WPC

Main focus last years: upscaling processes





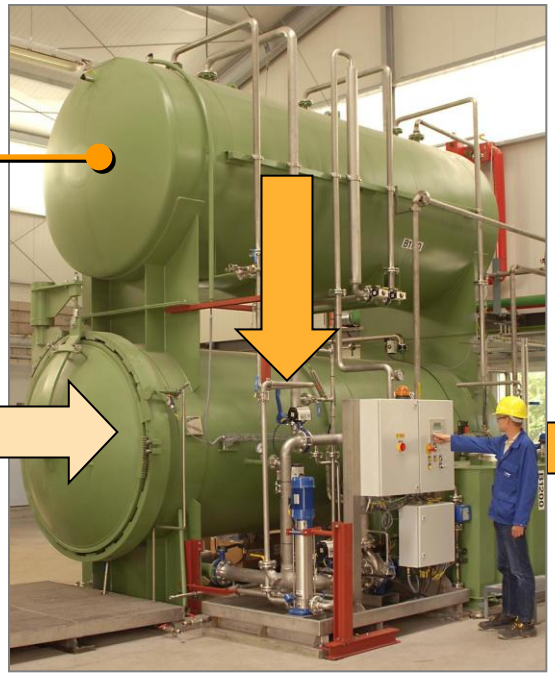
Belmadur® Technology

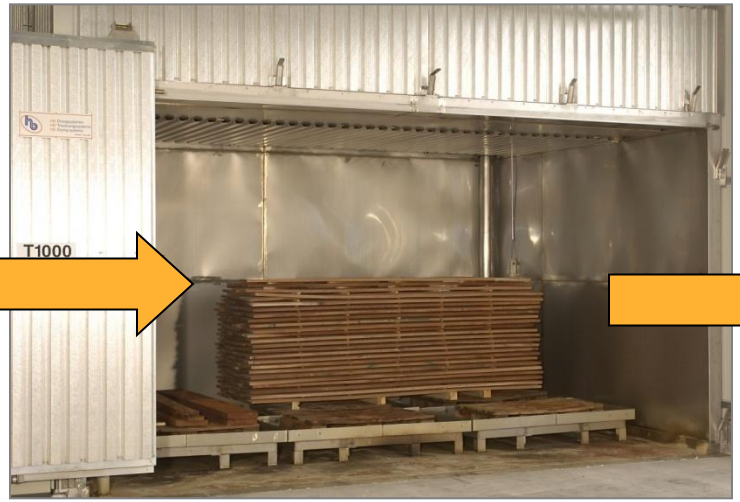
BASF
The Chemical Company

Wood **Treatment** **Curing** **Belmadur® Wood**

Belmadur®

Solution



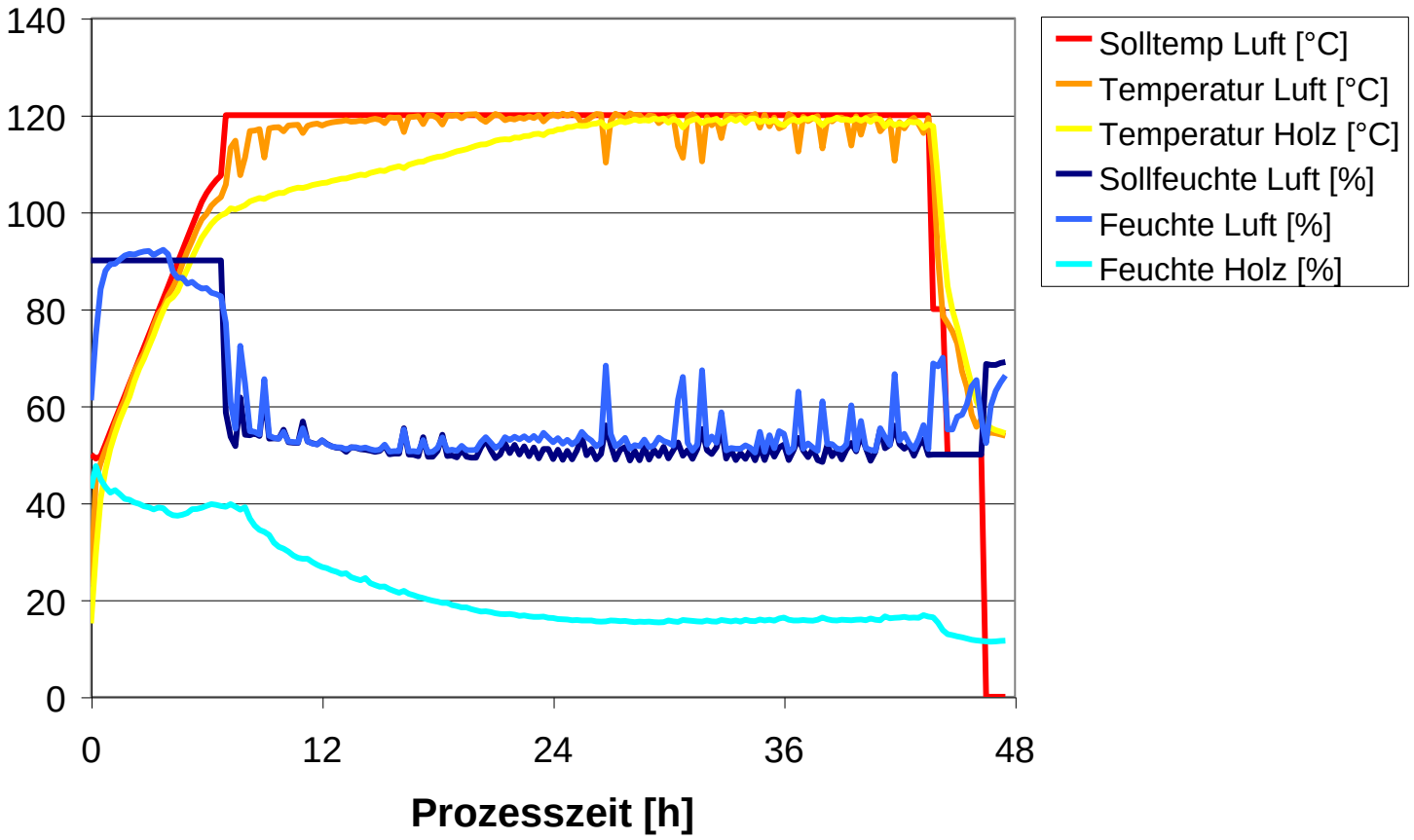


Room temperature

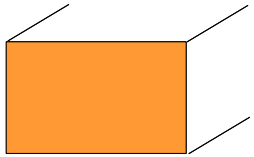
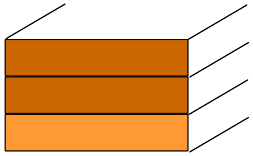
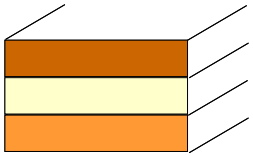
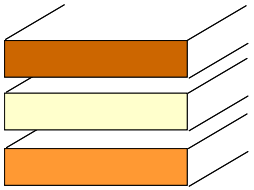
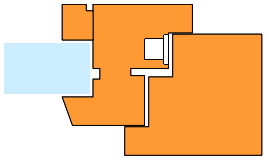
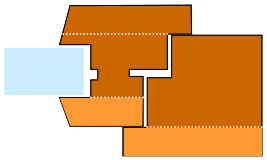
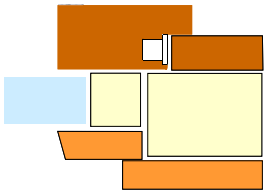
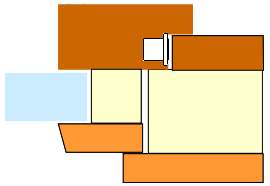
Temperature > 100° C

® = patent and registered trademark of BASF

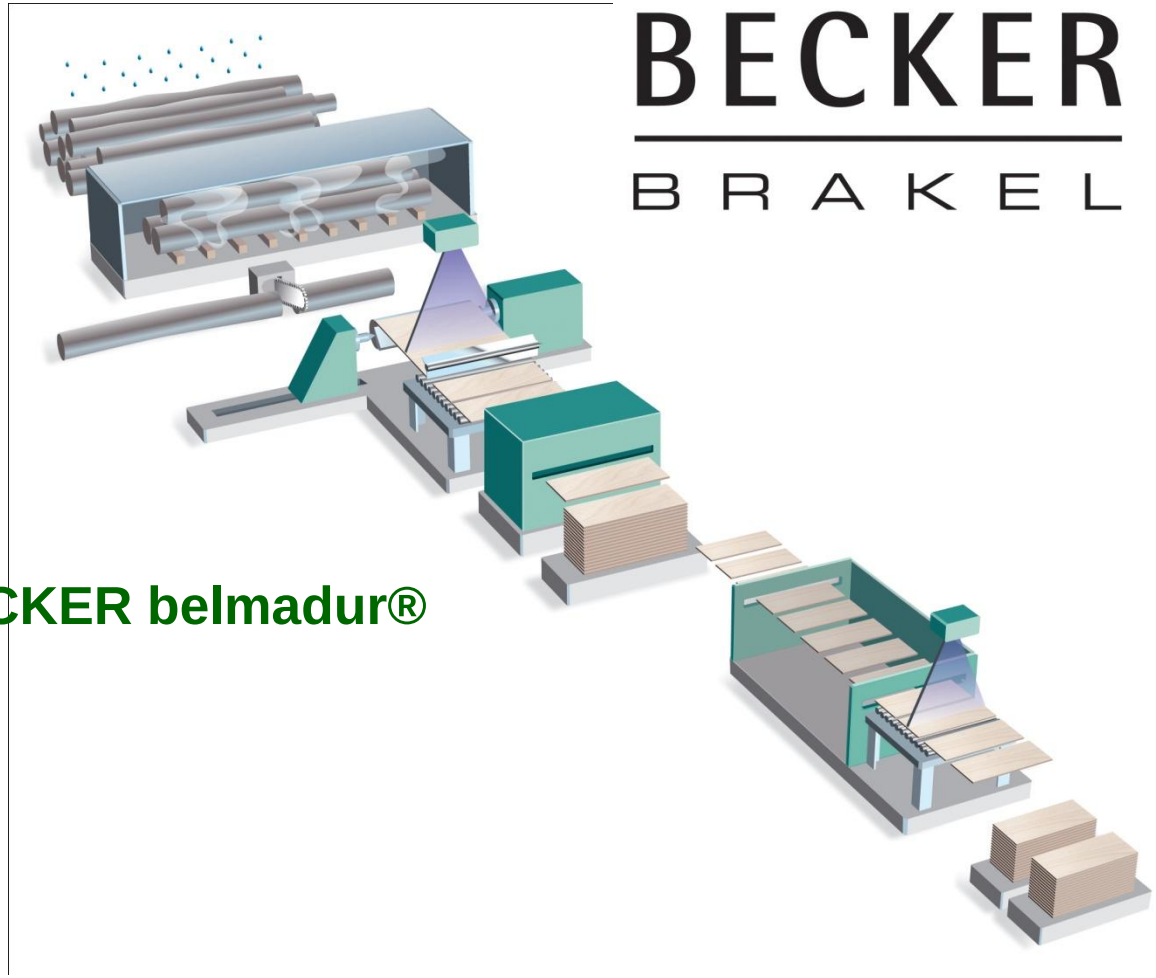
Superheated steam process



Development of construction

massive wood	wooden lamella	sandwich	functional layer
frames made from solid wood blocks	all lamella consist of same wood	Lamella consist of different wood	Choice of material regards the function
			
			

New product…new process…



BECKER belmadur®

DMDHEU particle boards

Treatment of particles in „reactor“

- closed system
- vacuum ~30 mbar (org. solvents possible [DMSO])
- temp. until 350 ° C
- volume 140 l
- treatment of approx. 10 kg particles and 6 kg fibres

Kebony® Technology

Furfural

Furfuryl alcohol

Basic materials

- Hydration from Furfural
- Furfural by distillation from waste of bagasse, corn, rice, peanut..

Kebony® production

Autoclave: 13 m length, 3.25 m diameter (0.1 - 13 bar)

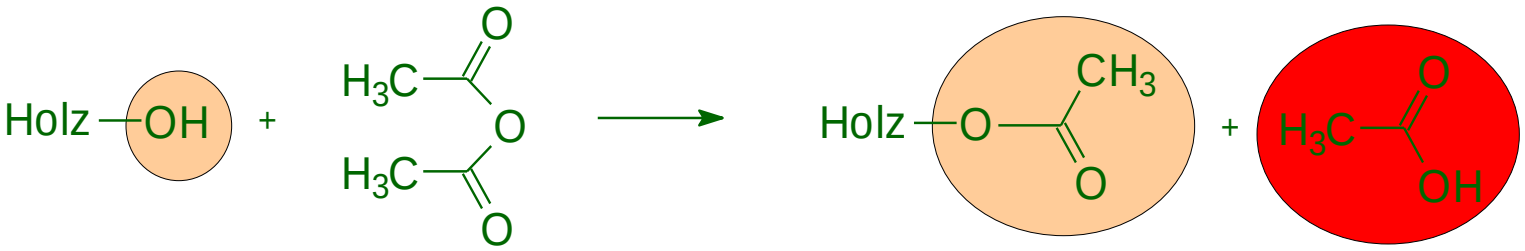
Kebony® products

www.kebony.com

Kebony® Products

Kebony® products

Accoya® Titanwood



Process:

- impregnation with acetic anhydride
- reaction at elevated temperatures
- post treatment (acetic acid)

Photos: SHR (NL)

Production plant, Arnhem, NL

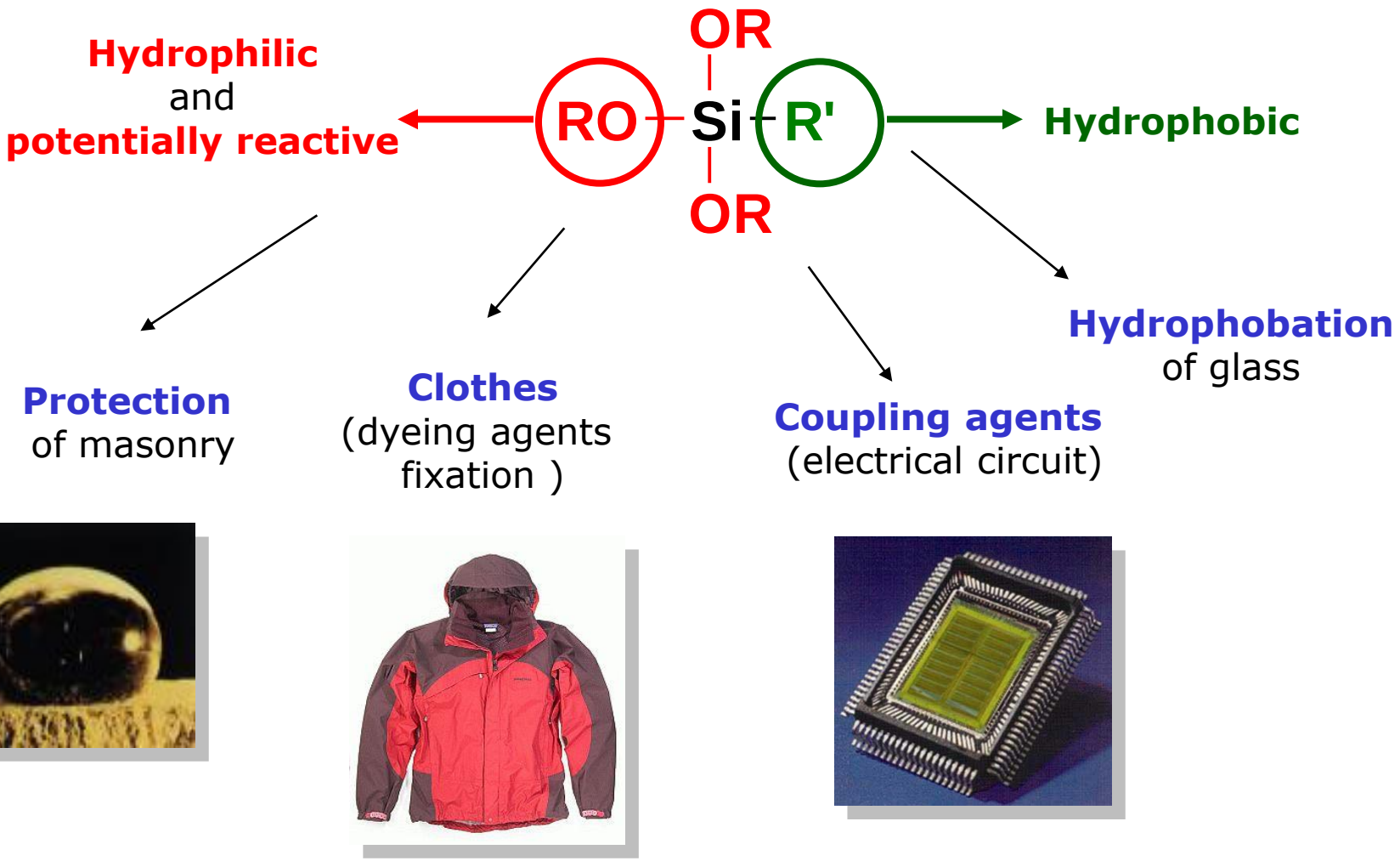
TITAN WOOD

Accoya® products

Bridge in Sneek (NL)

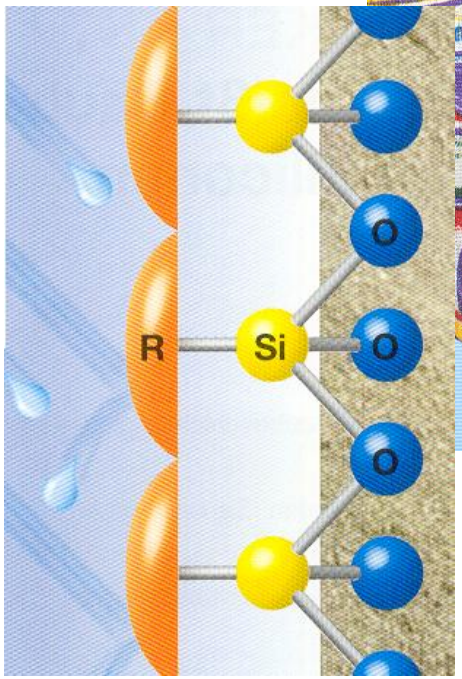
Lorry bridge (60t lorries, 40 m length)

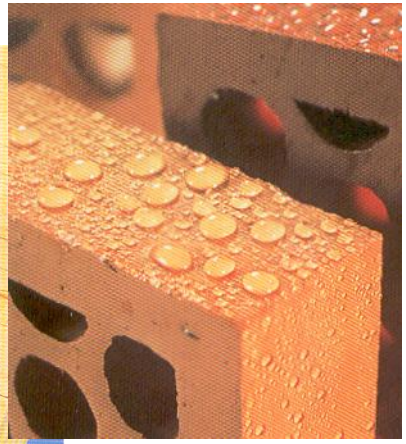
silicon based compounds



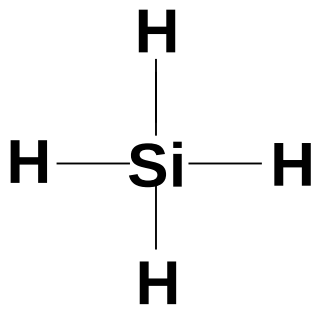
Silanes, silicones

“water shade effects”

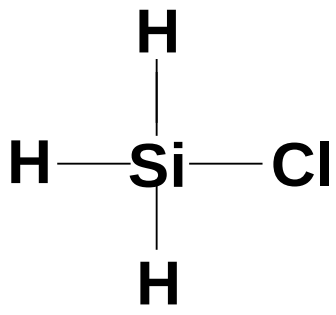




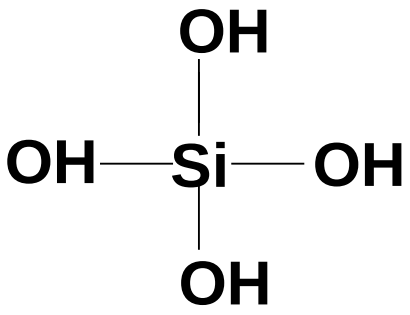
Introduction



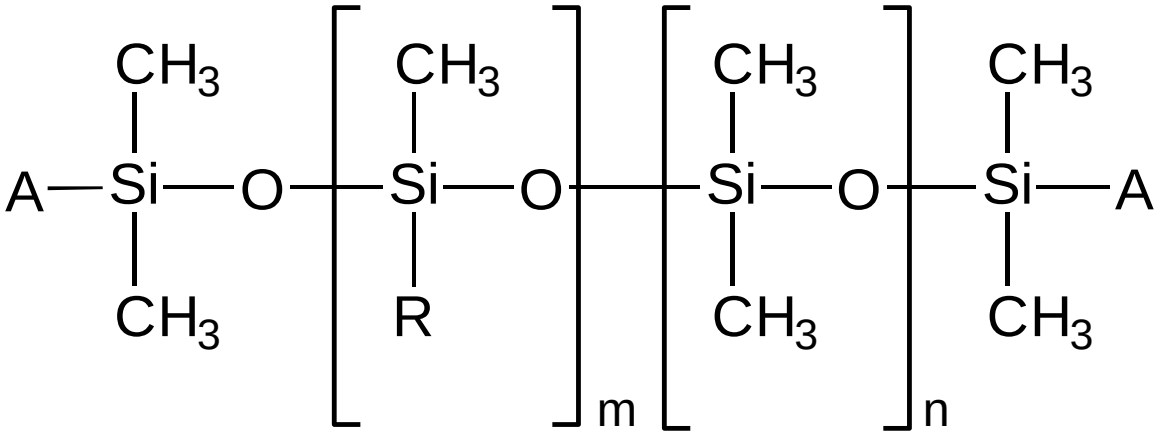
Silane



Halosilane



Silicic acid



Silicone

A = CH_3

R = $(CH_2)_3$-NH_2

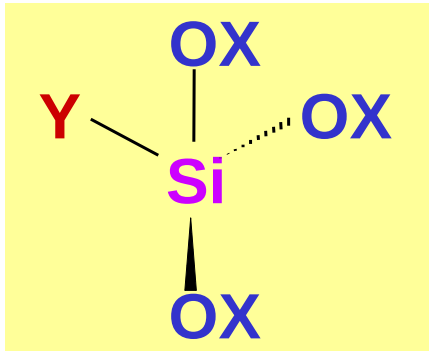
m = 7 - 10

n = 300 - 400

types of silanes

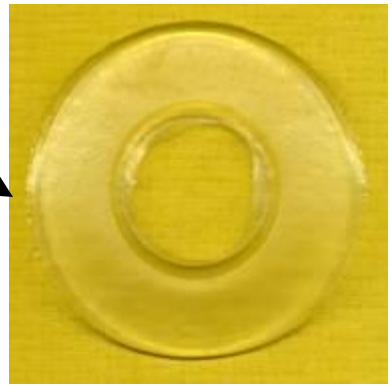
Y = “Organo-functional groups”

OX = “Silicone-functional group OCH_3, OC_2H_5 etc.



Tetraalkoxy
TEOS → SiO_2

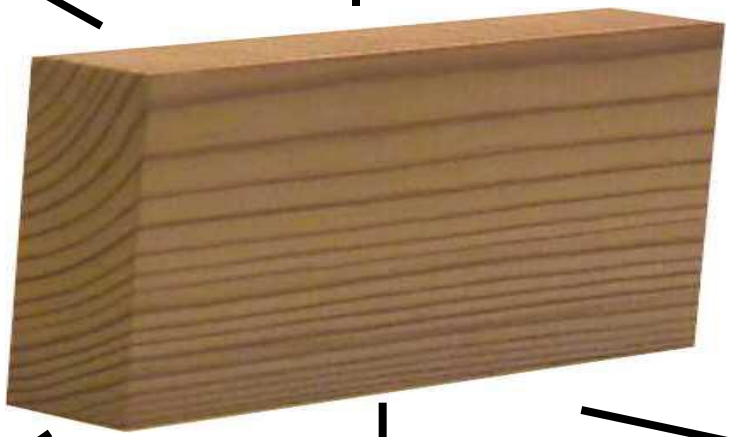
Methyltriethoxy
MTES → $Me\text{-}SiO_{3/2}$



Material properties

TMT: new material, new properties

FINNISH ThermoWood ASSOCIATION



Improved durability against decay

Reduced equilibrium moisture content

Reduced Thermal conductivity

Consistent colour through the piece

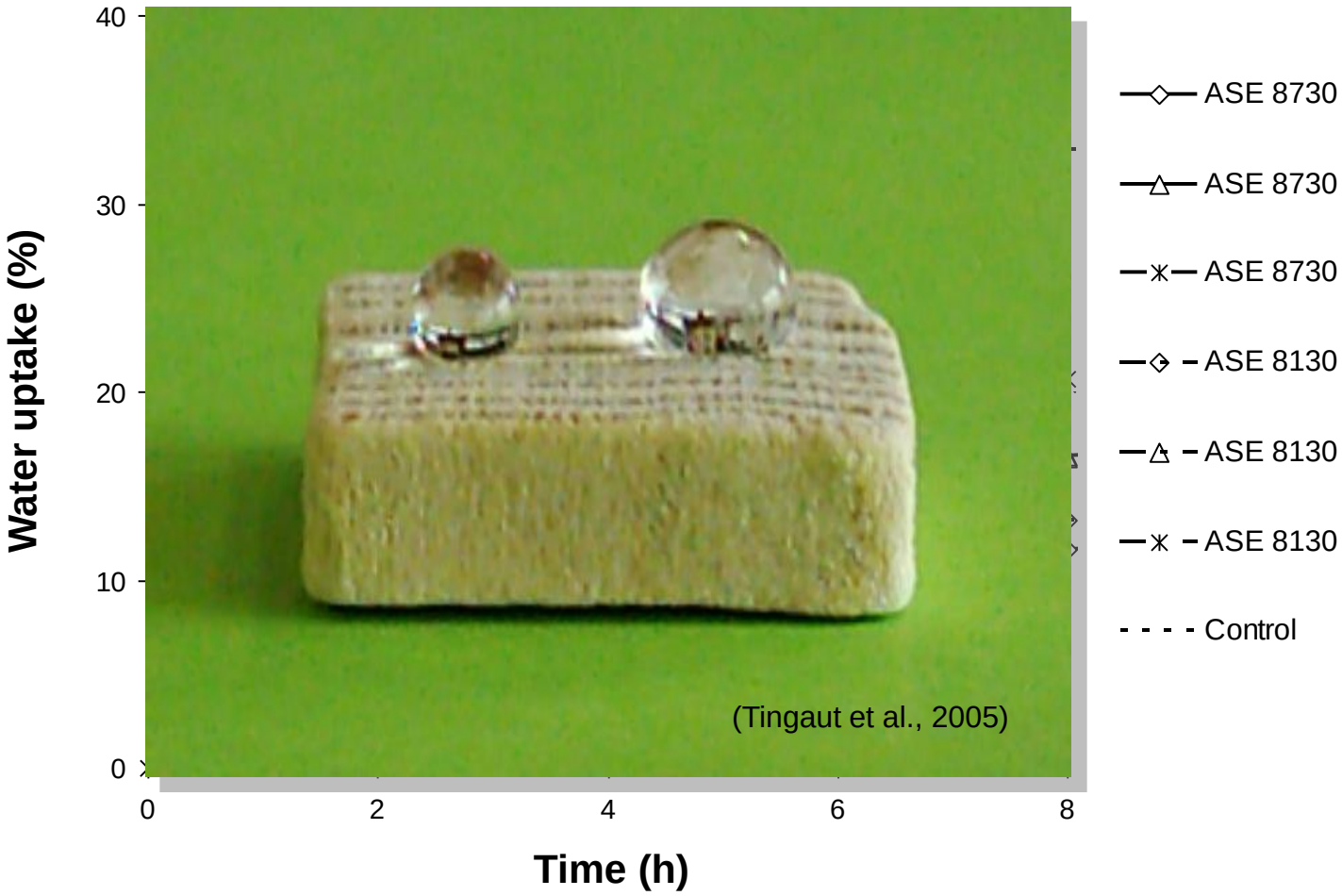
Resin removed

Reduced splitting strength

Improved stability

Slightly reduced bending strength

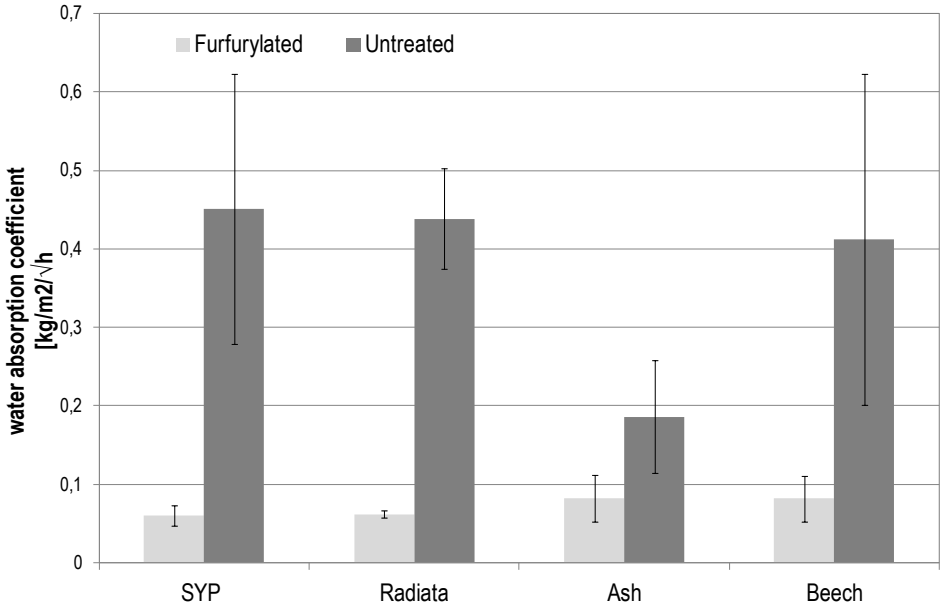
Water uptake

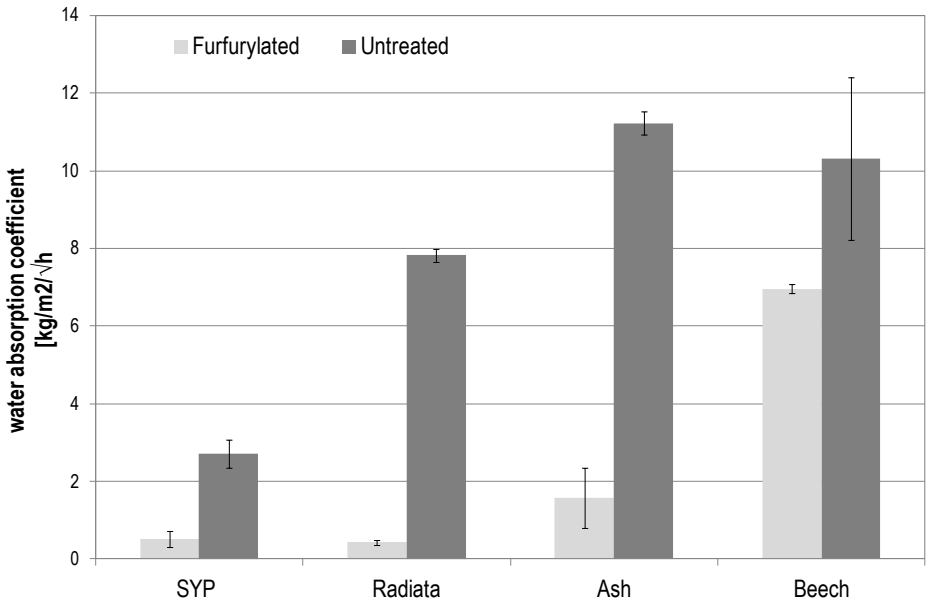


Capillary water uptake

- water absorption coefficient shows the water uptake in relation to time [kg/m²/√h]

- Reduced water uptake after modification





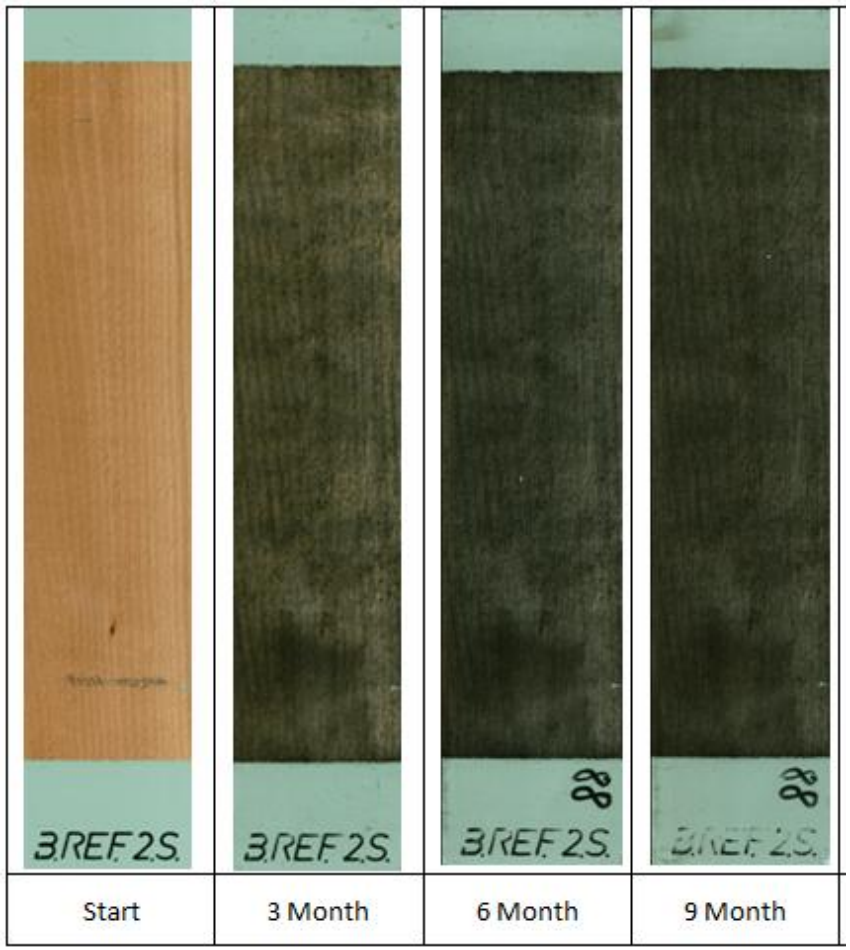
Water absorption coefficient [kg/m²/√h] in tangential (left) and longitudinal direction (right)


DV15-1
DV03-4

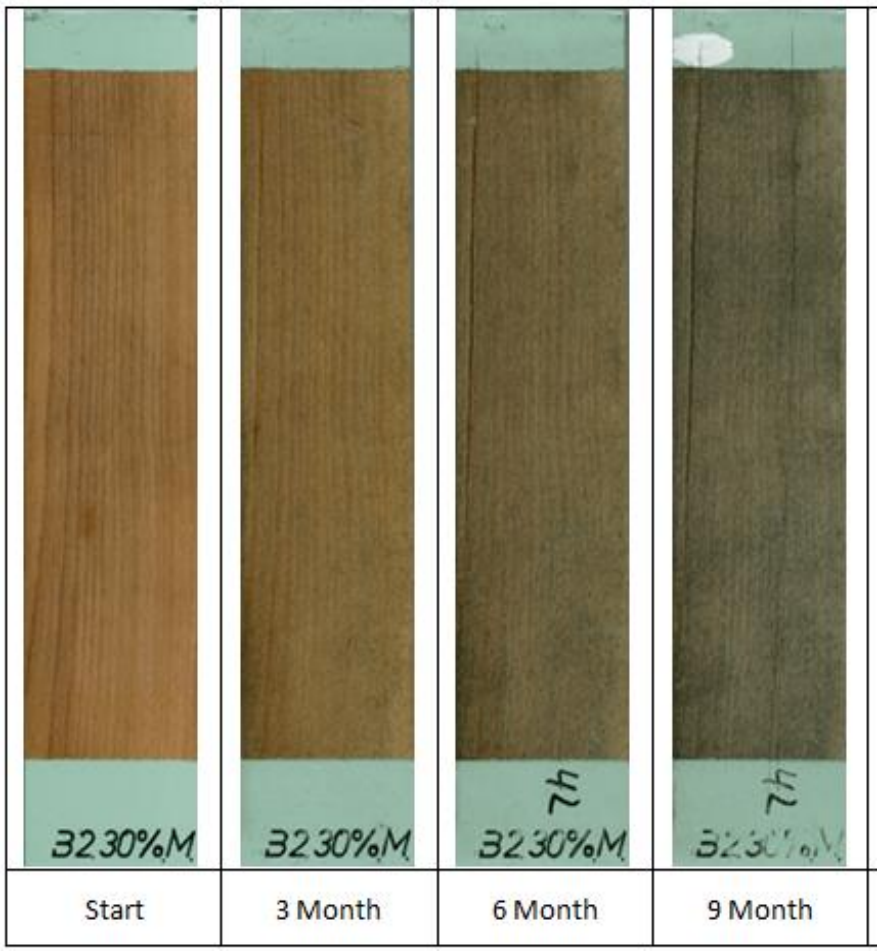
Material evaluation

Modified hardwood at natural weathering test according to EN 927-3

Surface appearance



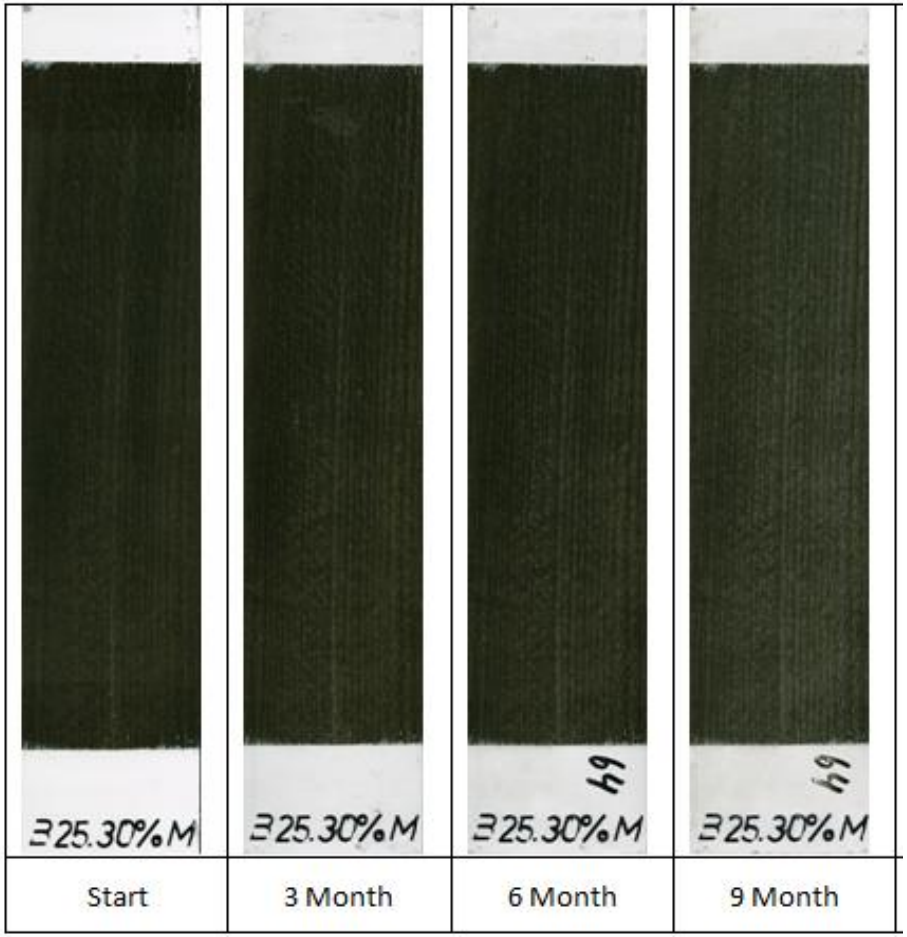
Beech control



30% NMM modified beech

Surface appearance

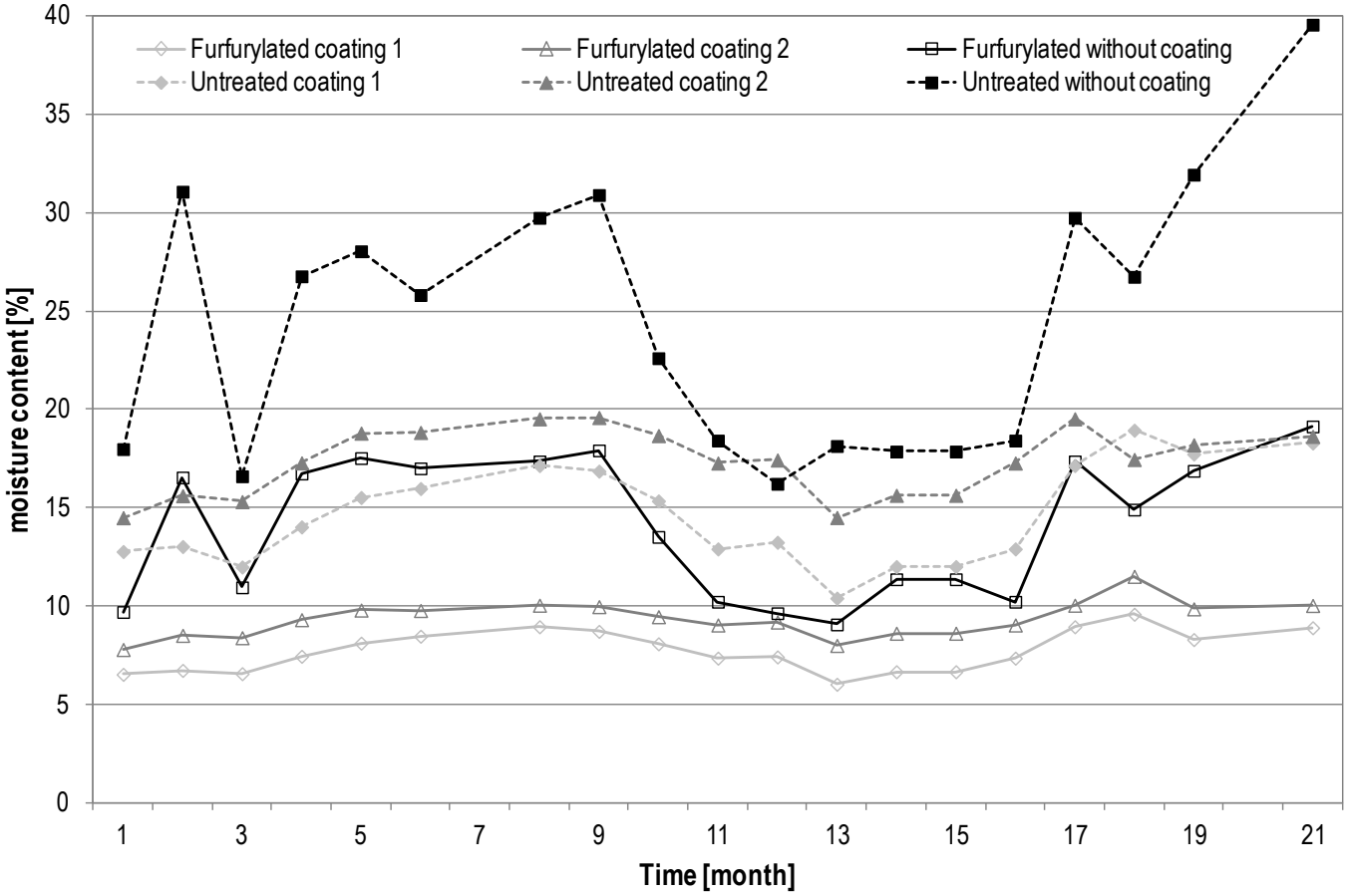
30% NMM-BS yellow modified beech



30% NMM-BS brown modified beech

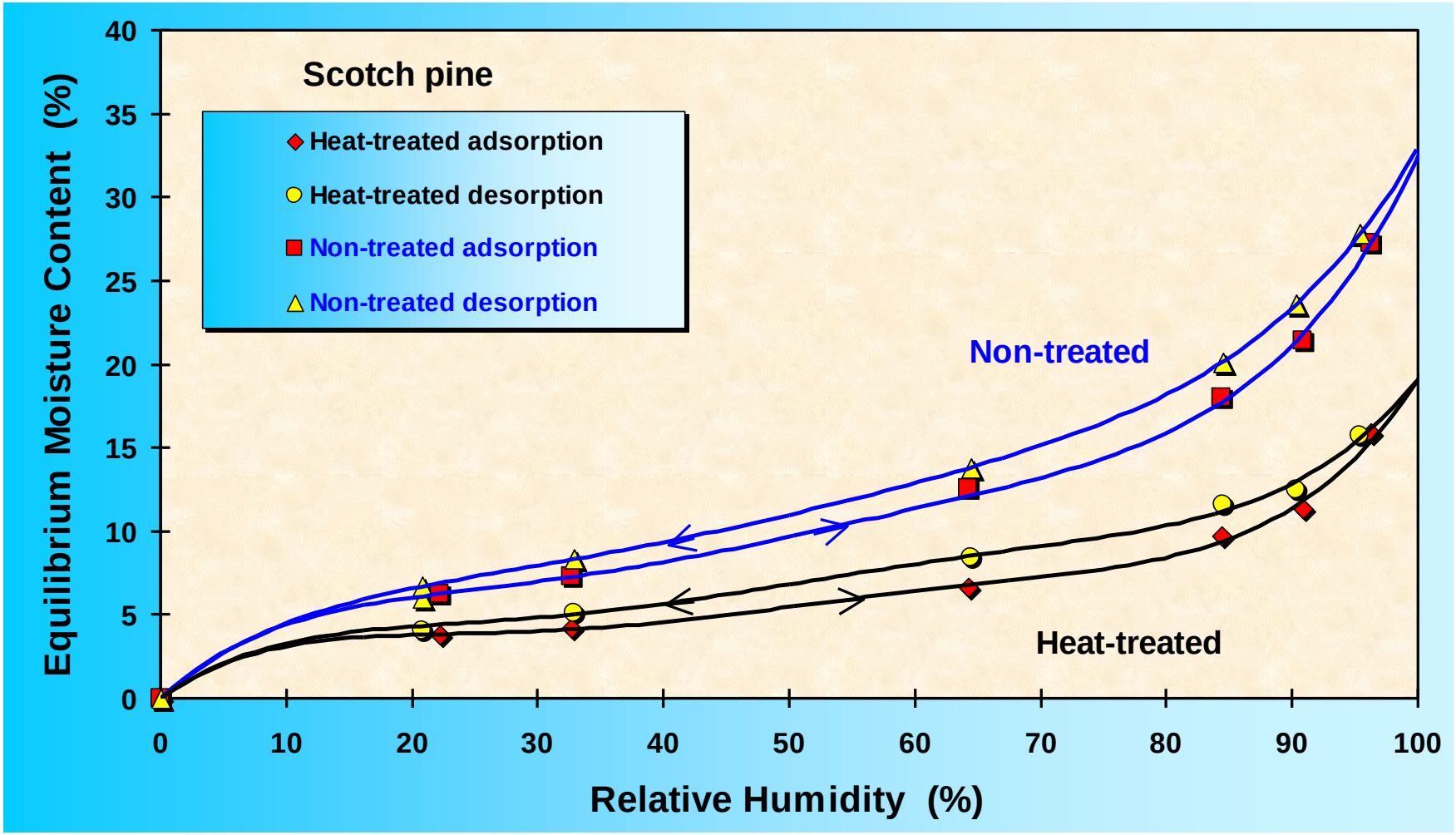
Outside weathering - results

- significant lower m.c. than untreated material
- uncoated furfurylated is lower than untreated/ coated

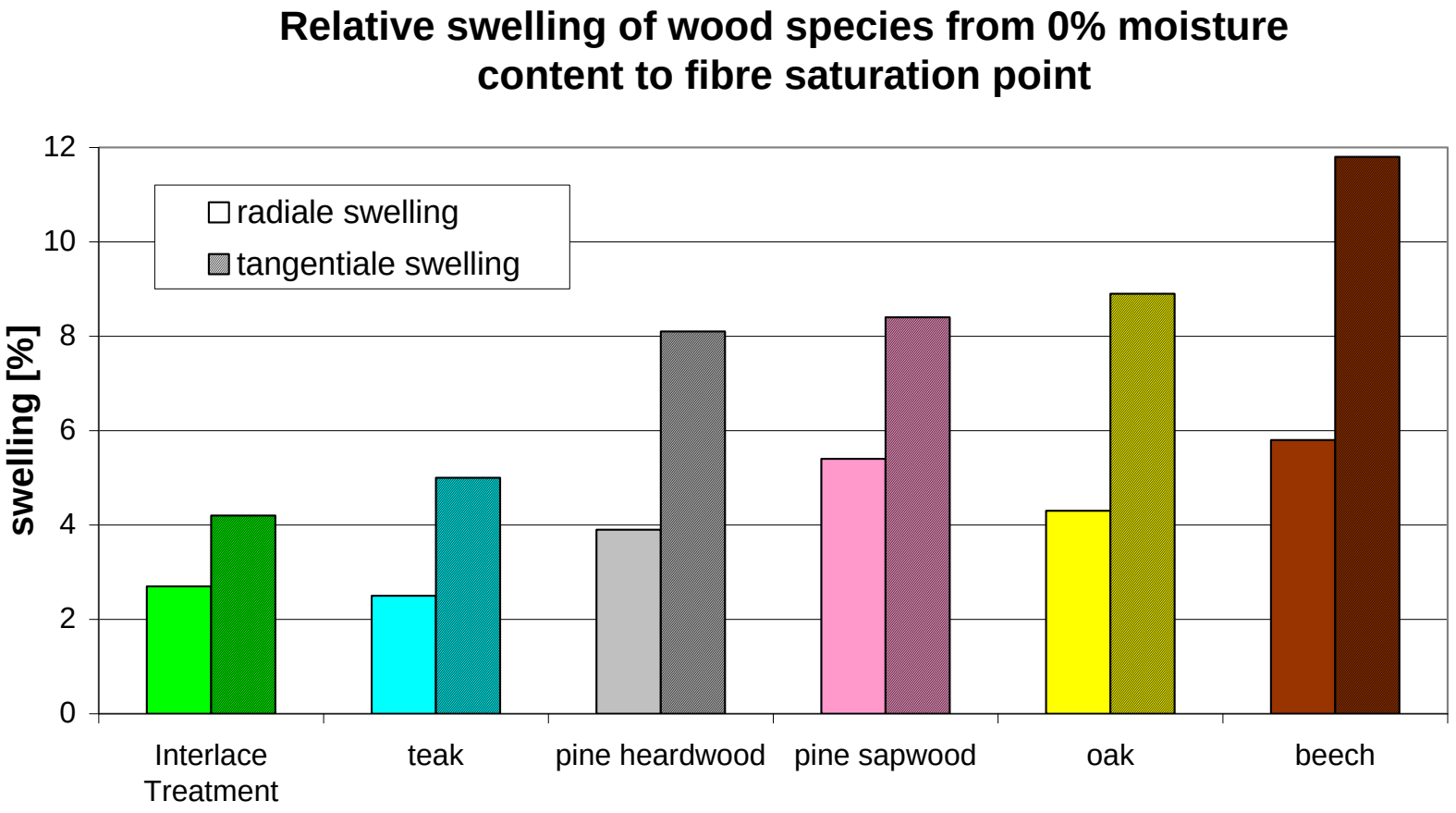


Moisture content [%] of SYP samples over a period of 21 month

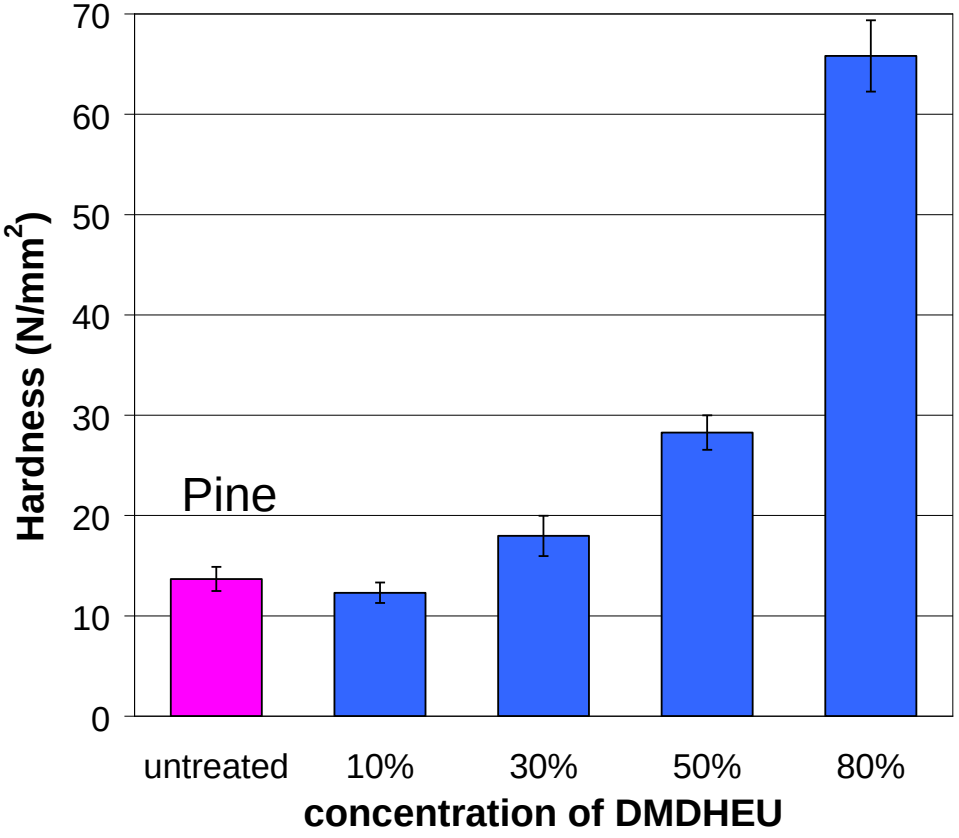
Sorption properties
(Tjeerdsma, Boonstra 1990´s)

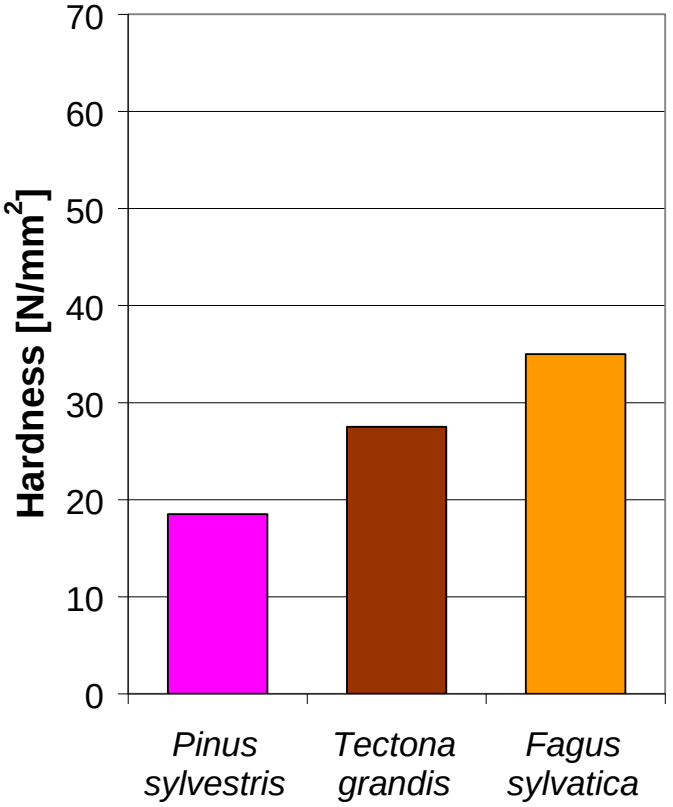


Swelling and shrinking of wood species



Brinell hardness (parket flooring)

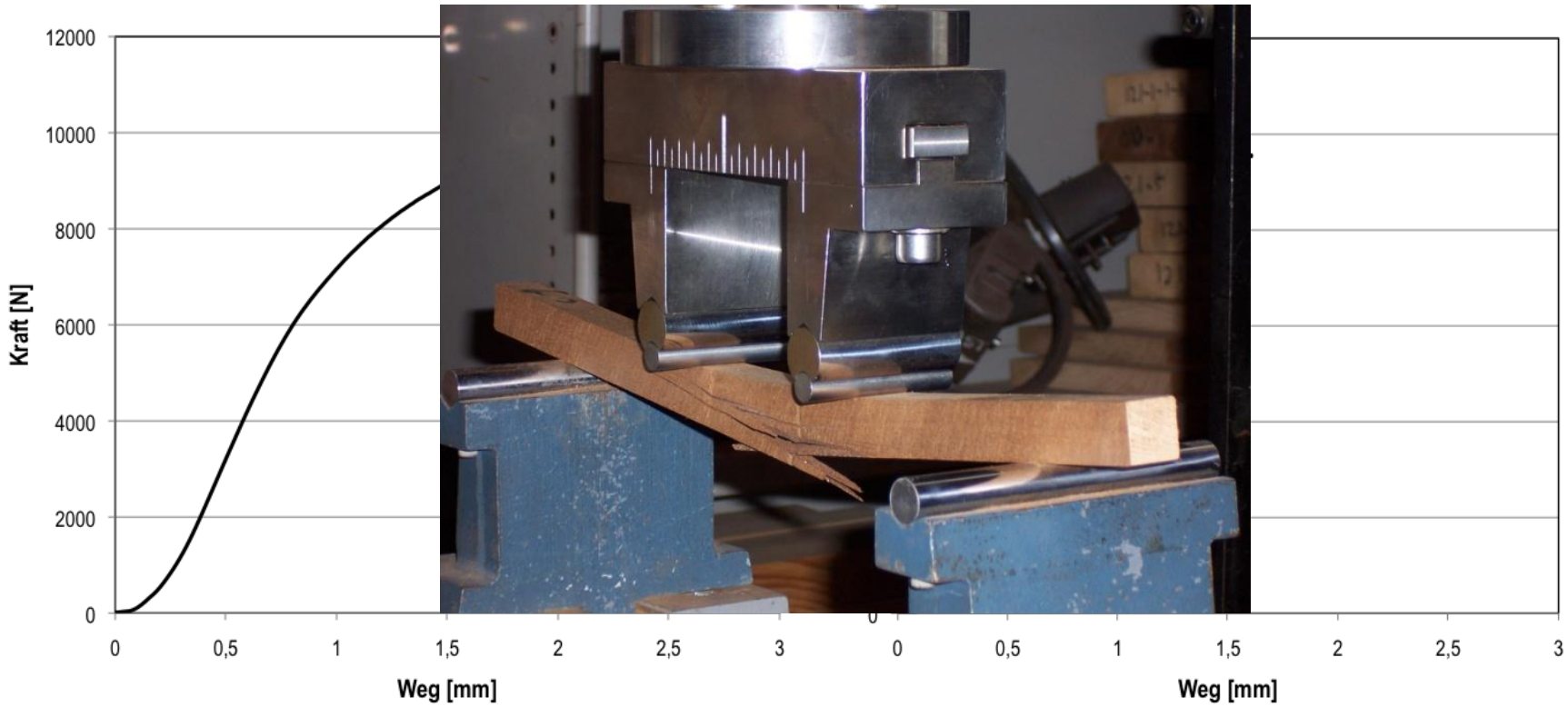




Strength testing: MOR bending mode
(Bollmus 2010)

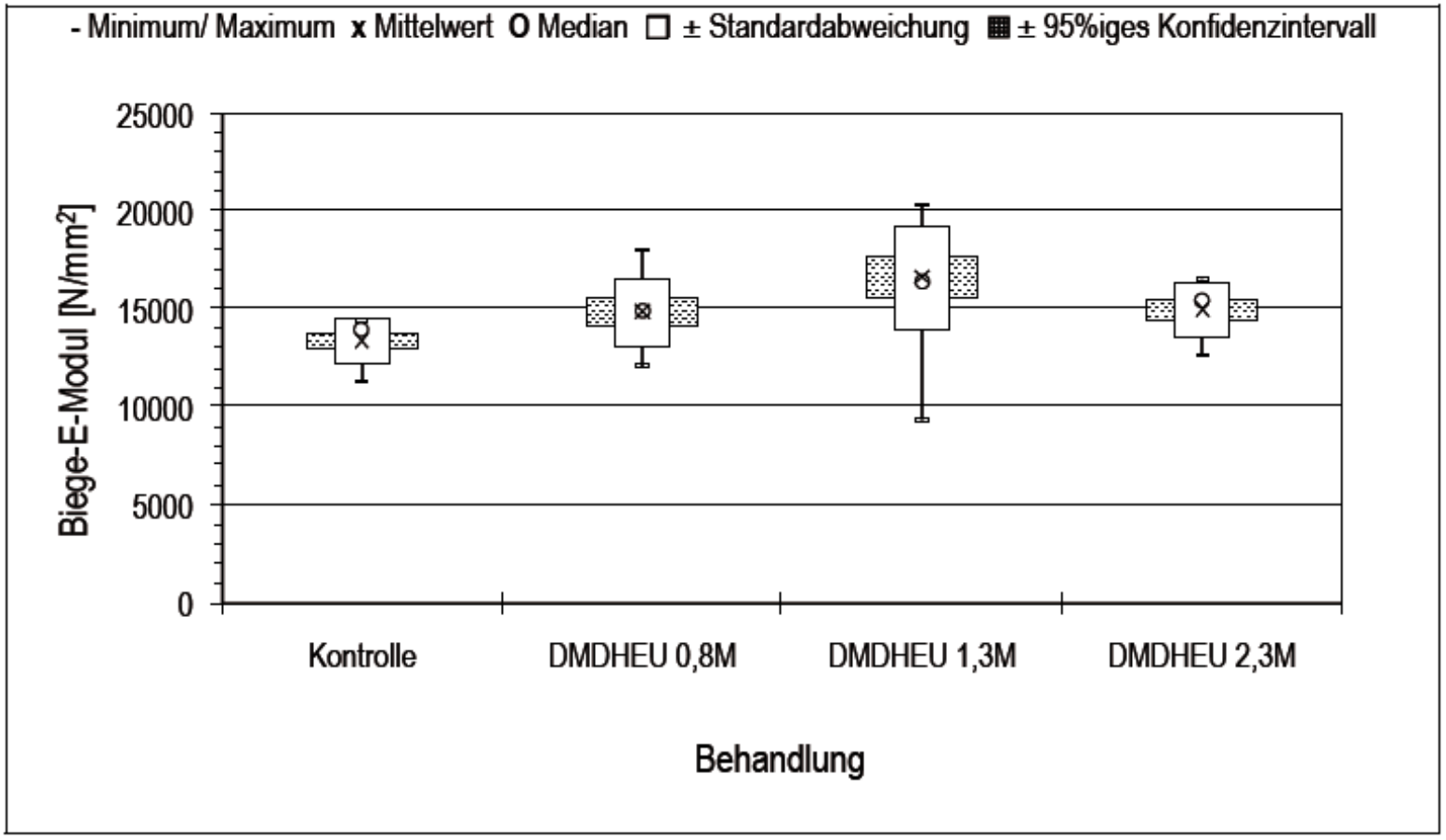
control

Methylol treatment

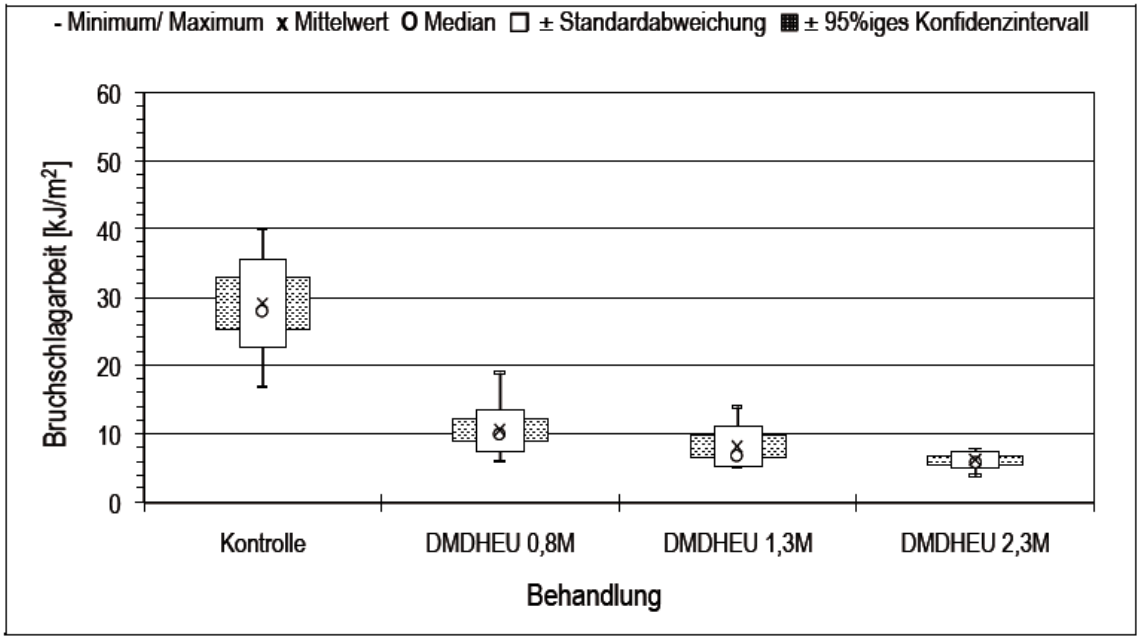


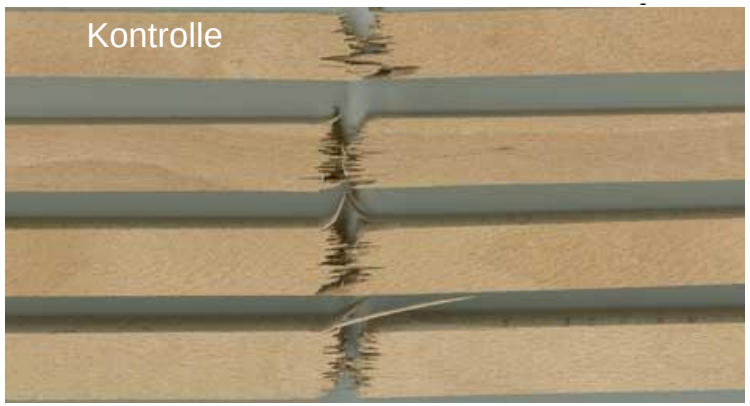
MOE in bending mode (DMDHEU)

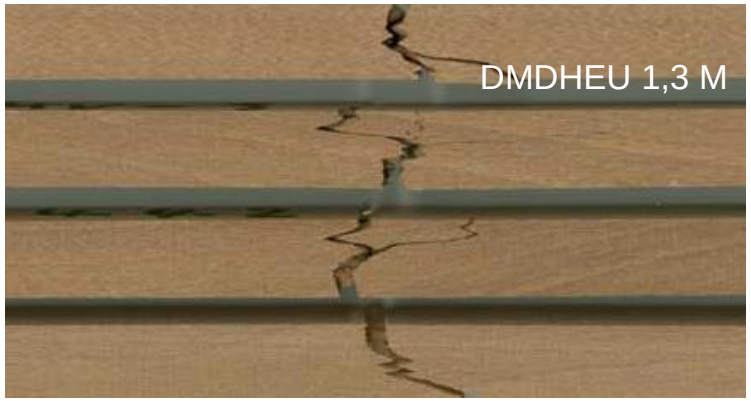
(Bollmus 2010)



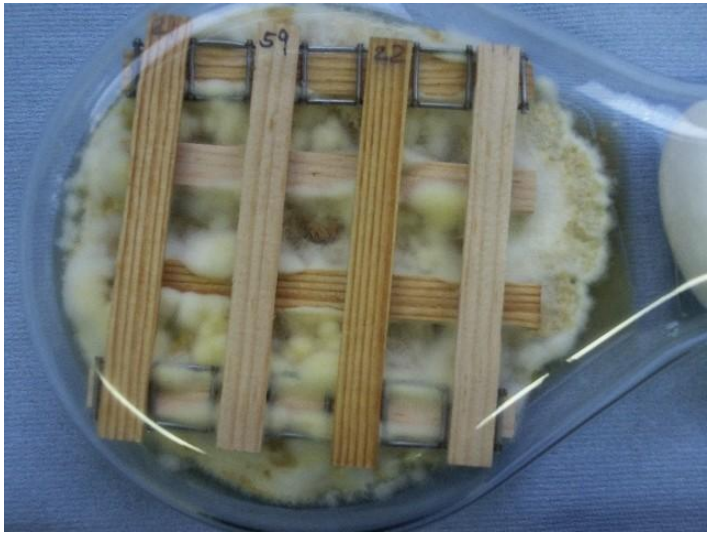
Impact bending strength
(Bollmus 2010)





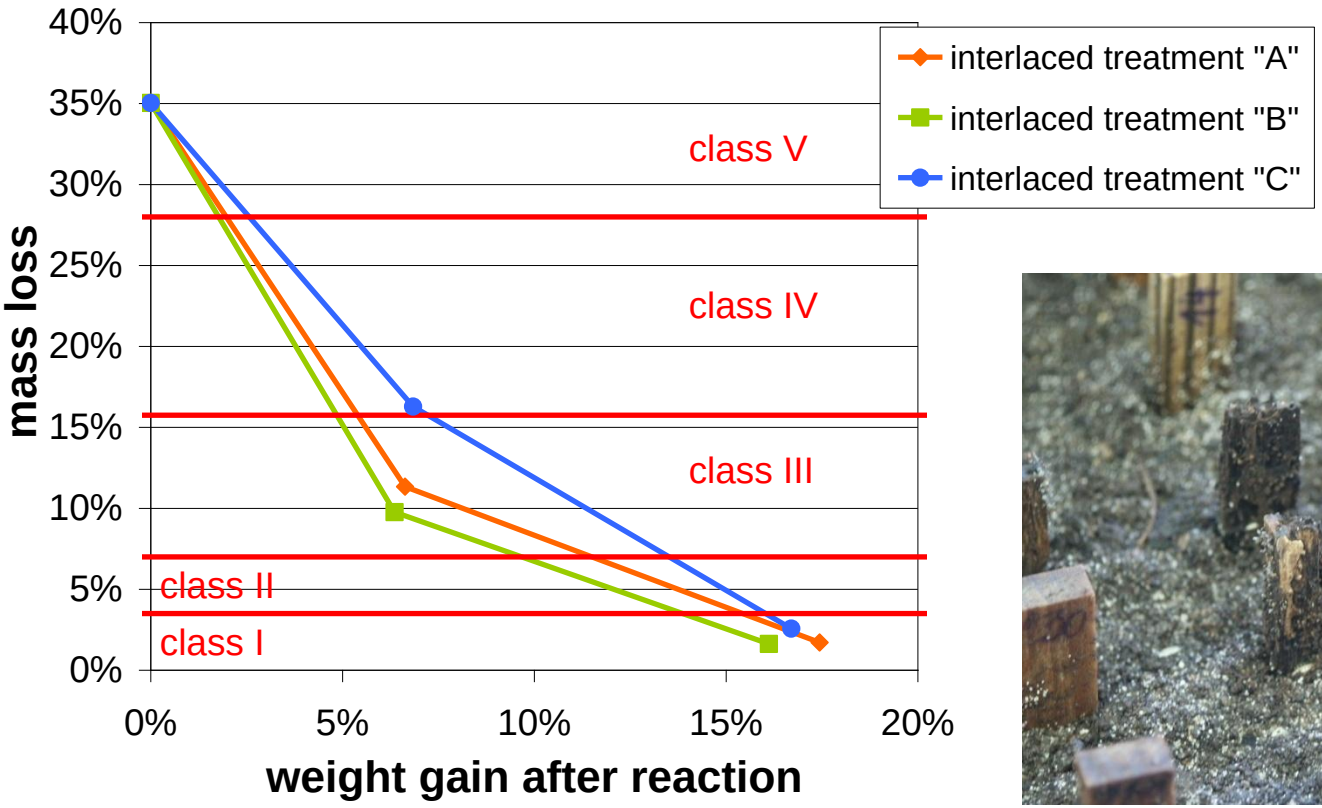


Biological testing of new materials



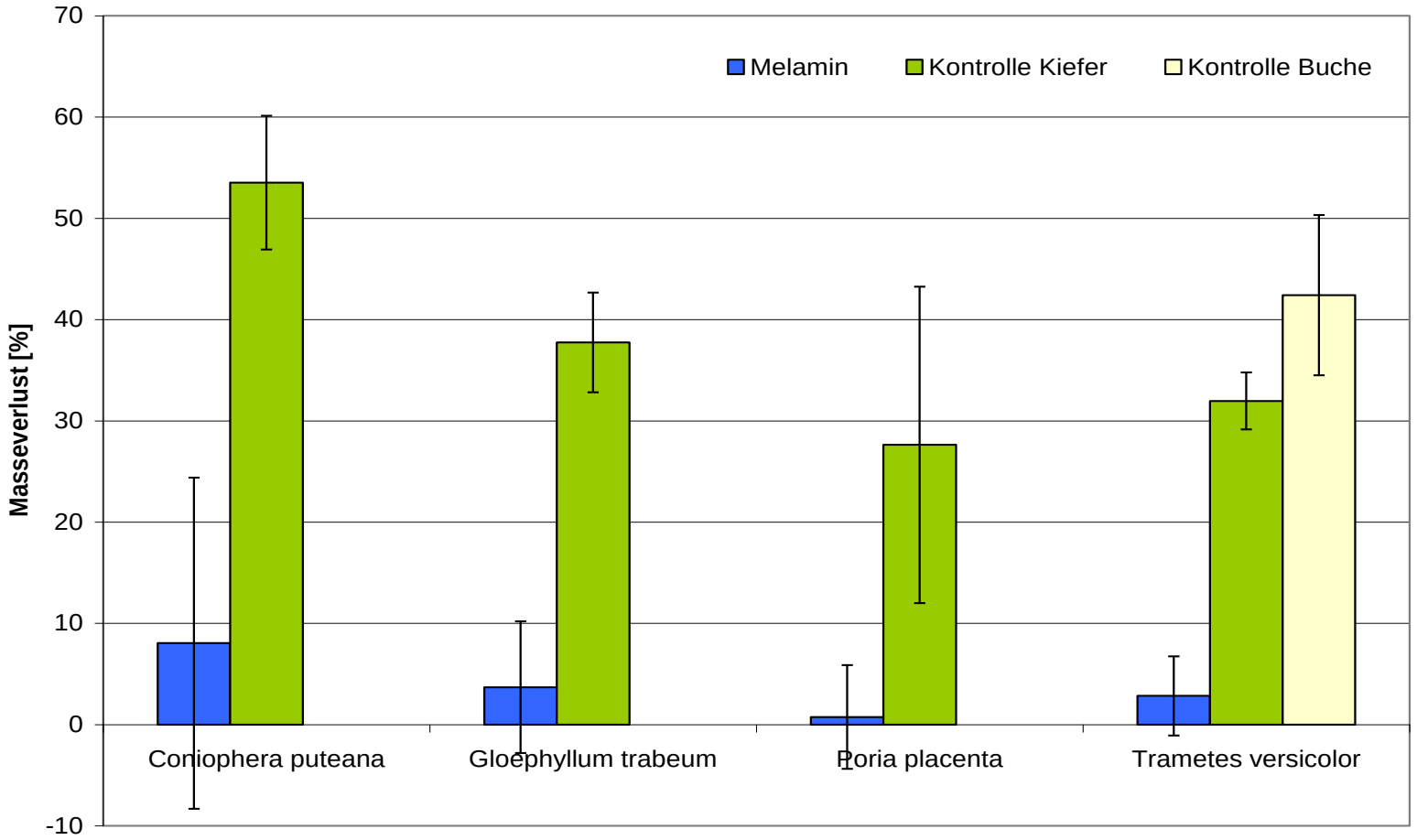
- Biocidal action?
- Solely lab testing?
- Performance testing in field?
- Product testing?

Degradation of beech wood after 32 weeks in soil contact (ENV 807)



Main material properties gained with NMM

- Durability improvement



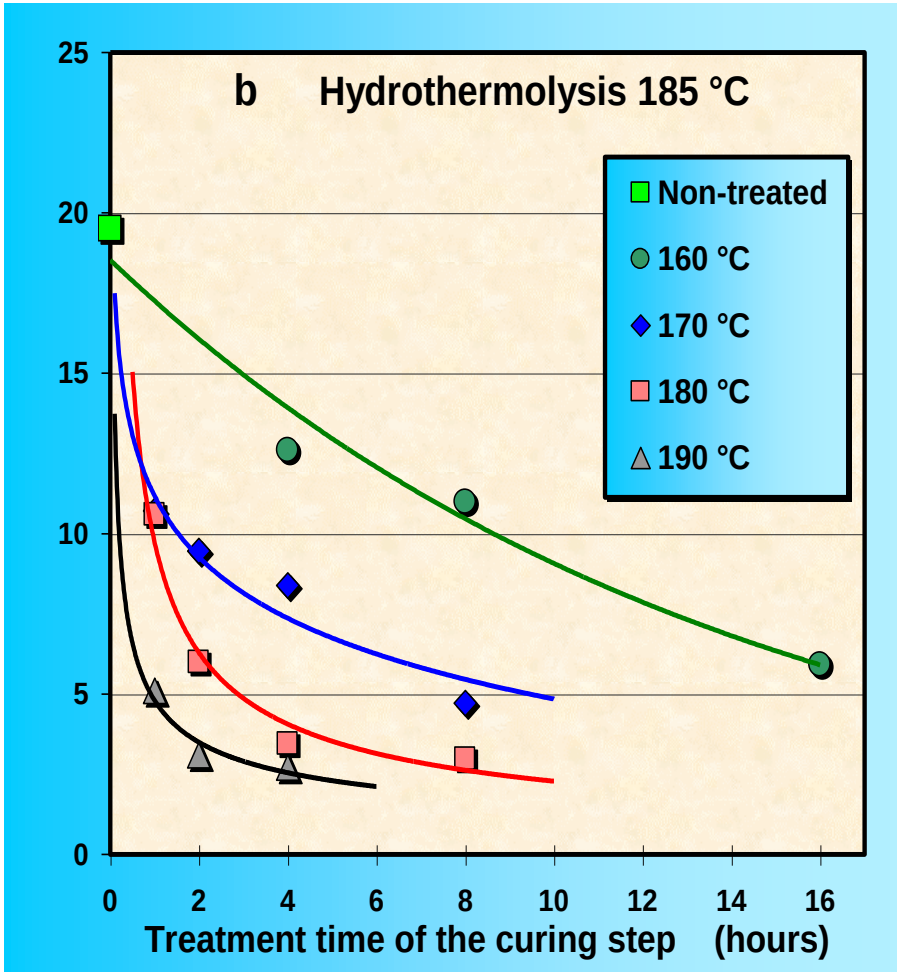
Pine modified with 10% NMM after 16 weeks EN 113; DBU-Report, Az: 26869 (2009)

Fungal resistance as function of process conditions

(Tjeerdsma, Militz 2002)

Pinus silvestris

- Soil block test
- Weight loss after 54 weeks



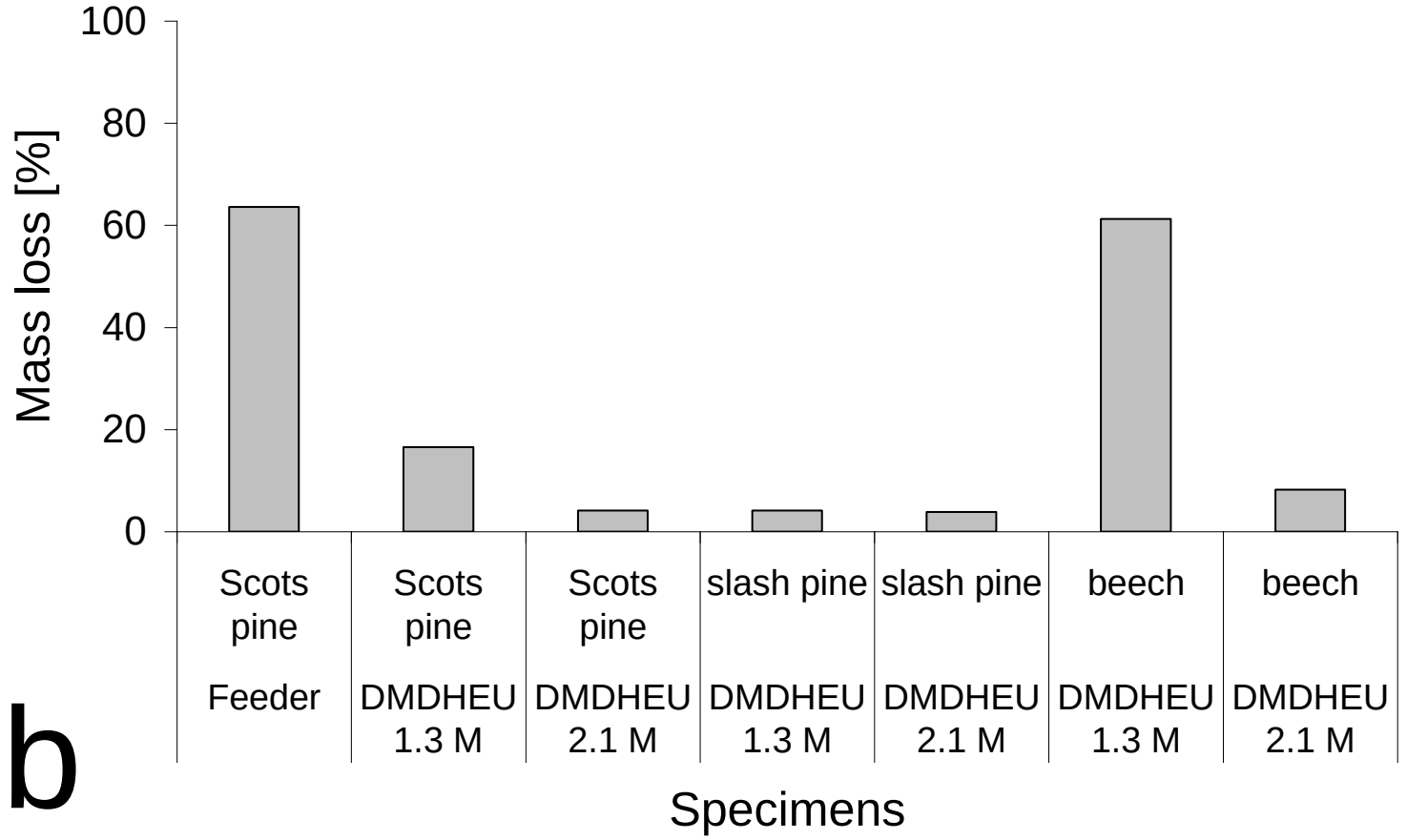
Termite resistance: test fields Australia, Portugal, lab tests Spain

General results: Coptotermes/ Mastotermes

· Es

- Heavy attack in both fields (adequate feeding pressure)
- Pinus sylvestris controls
  - Sapwood 100 % attacked
  - Heartwood well protected

Results *Coptotermes acinaciformis*



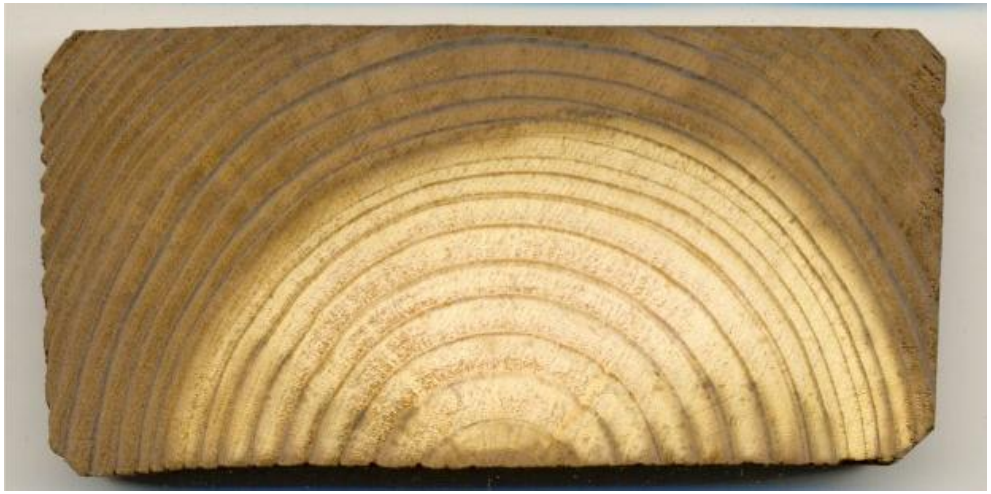
b

Challenge: wood species

- Selection of right wood species
  - What are criteria?
  - macroscopical versus microscopical distribution of chemical

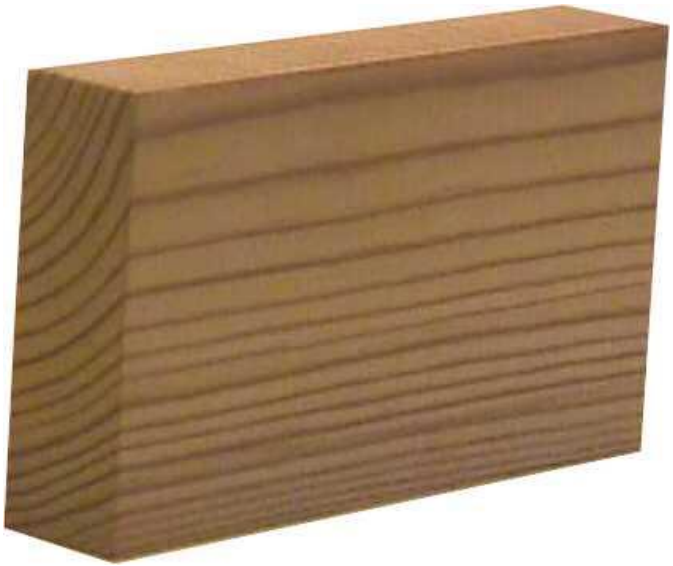
Wood – Treatability / Permeability
(Photos by Kebony)

Obvious effect for impregnation technology



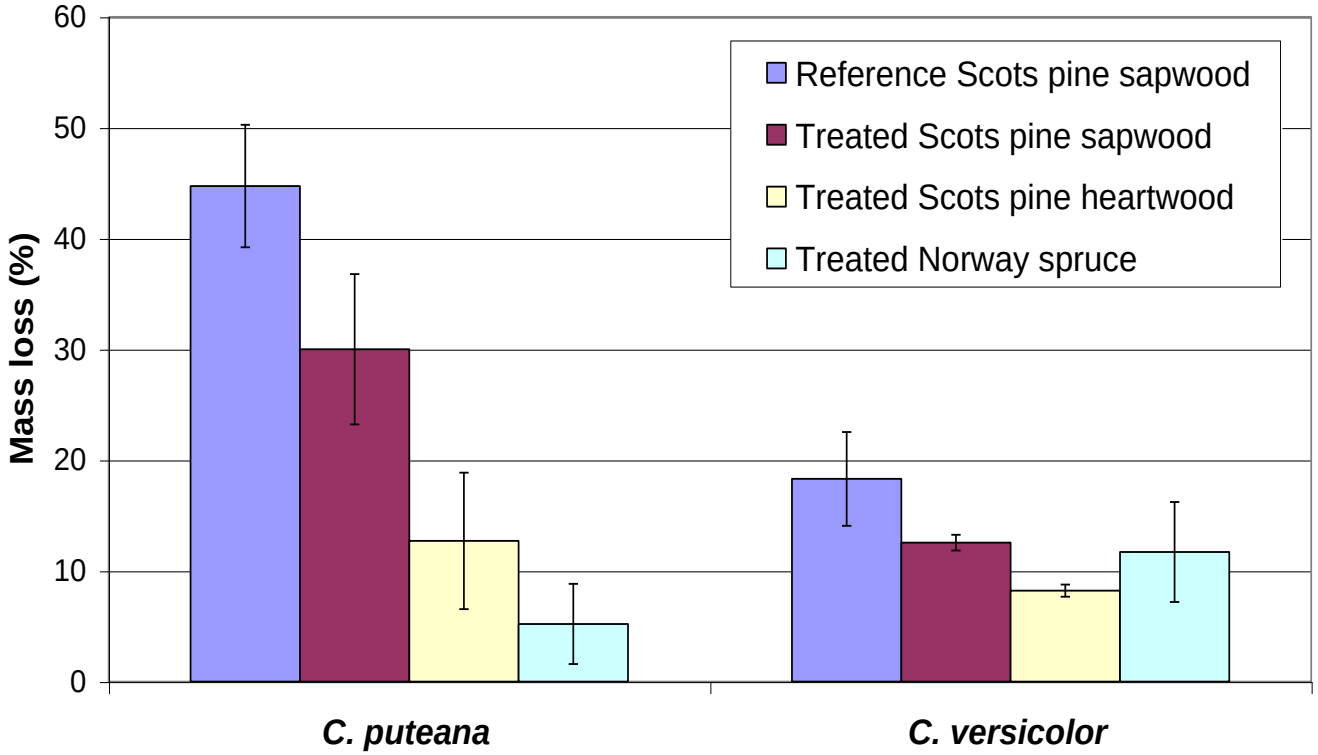
Wood – Treatability / Permeability

No **obvious** effect for thermowood



Durability of heat treated Pine and Spruce

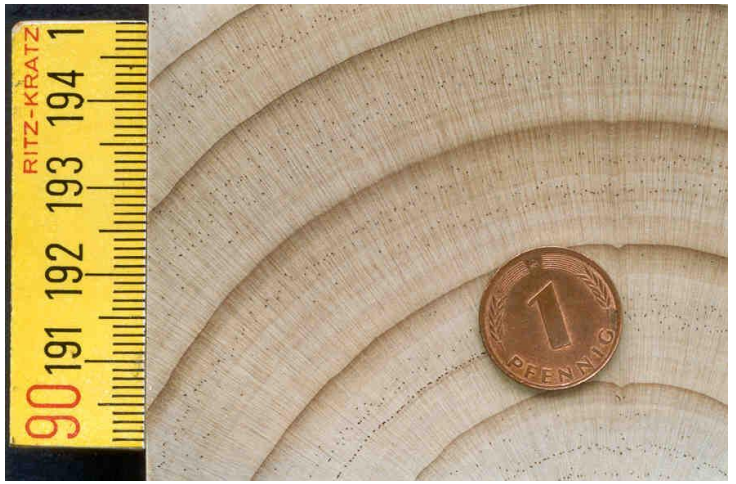
(PLATO process, Boonstra 2008)



- Mass loss of treated and untreated Spruce/ Pine
- Incubation with *C. puteana* and *C.versicolor*
- Test standard: CEN /TS 15083-1

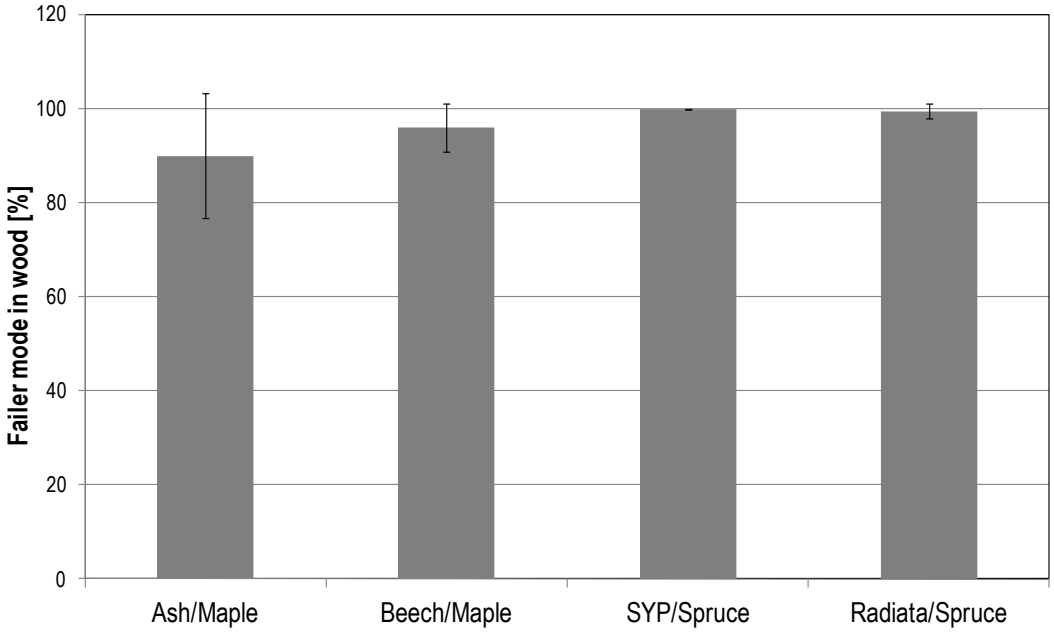
Basis materials for wood modification

- Easy „treatable“
- Large quantaties
  - Pines
  - Poplars
  - Beech?
  - Eucalypts?
  - Ash? Alder?
  - Other fast growing wood species!



Glueability of scantlings

- Cleavage test
  - 85-100% failure mode in furfurylated material
  - For fulfillment of the standard, ≥ 90% of wood failure is required
  - All wood species met the requirements of the standard



Failure mode [%] in wood after cleavage with a planer blade

Challenge:
processing, costs and markets

Other factors of concern to clients…

- Environmental concerns
  - Emissions to air
  - Emissions to water
  - Human tox
  - Eco tox
  - Working environment

Furniture, Thermowood

- Machinability and further processing
  - Tools
  - Material homogenity
  - Glueability/ paintability
  - End product performance

- Disposal/ recycling
  - Reuse of fibres?
  - Energy – burning?
  - Land fill

Potential markets for modified wood

Outdoor
- Decking
- Roofing
- Utility poles
- Rail ties
- Fences
- Garden furniture
- Bridges
- Marine applications
- And more…

Indoor
- Flooring
- Windows
- Doors
- Furniture
- Mouldings
- And more…

Decking, Accoya

Roofing, Kebony

Floor, Kebony

Bridge, Accoya

Decking, Belmadur

Chair, Belmadur

Challenge: markets

- Biocide treated wood
  - Costs!!
  - Special products
- Markets of tropical hardwoods
  - use classes 1-5
  - „high quality“
- Special products with diverse functions

ECWM European Conferences on Wood Modification

- ECWM 6: Sept. 2012 in Ljubljana, Slovenia
- ECWM 2014: Lisbon/ Portugal
- ECWM 2016: Helsinki/ Finland
- (Proceedings ECWM 1-6: contact me!)

Thank you for your attention!

10 % NMM, 20 x magnification, ash