Introduction to Modified Wood

COST Action FP1407 Training School

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Outline

- What happens during weathering
- What is modified wood?
- Why does modified wood work?
- Case study: thermally modified larch

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Weathering: what is happening?

Ultraviolet light:

Degradation of the lignin which holds the wood cells together

Rain:

Removal of degraded lignin, and erosion of wood cells

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This can be a beautiful thing!

Image: Russwood

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But new modified wood offers a solution

Often:

- Better durability
- Lower moisture movement
- Better life-span for paints and coatings
- Different weathering profile compared to untreated wood

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What is wood modification?

Three main technologies:

- Chemical modification
- Resin impregnation
- Heat treatment

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Chemical modification

- Reaction of small organic molecules into the structure of the wood
- e.g. Acetic anhydride
- Accoya
- Blocks access by water to many of the hydrophilic sites within the wood cell wall
- Typical equilibrium moisture content at 20 °C and 65% r.h. is 3.3%

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Chemical modification

- e.g. DMDHEU
- Belmadur
- Commonly used in textile industry for crease-resistant fabrics
- Reacts with hydroxyl groups in the cell wall
- Forms a bridge between microfibrils
- Prevents swelling

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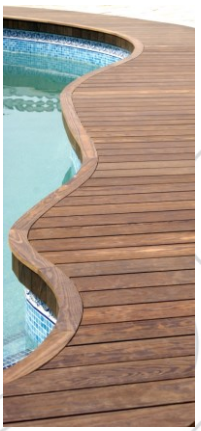
Chemical modification

- e.g. furfuryl alcohol
- Kebony

- A by-product of sugar cane refining
- Reacts with hydrophilic groups in wood cell wall
- Prevents access by water molecules
- Some bulking of the wood wall



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Resin treatments

- e.g. Lignia,
  Indurawood, Alowood, Vecowood

- Use of resins to impregnate the wood
- Resin is cured in situ
- Physical barrier to prevent moisture accessing the wood cell wall
- Physical restriction on dimensional change
- Sometimes combined with pressure to densify the timber

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Polymer treatments

- e.g. methacrylate polymerisation
- No current commercial production

- Polymerise the monomer inside the wood cells
- Transparent polymer fills the macro voids in the wood
- No grafting to the wood itself

- Interest in 'transparent wood' uses this technology on a bleached wood substrate

Li et al. (2016) Biomacromolecules 17:1358-1364

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Thermal modification

- e.g. Thermowood, Lunawood

- Applying high temperatures (180°C to 250°C) to dry wood
- Thermal changes to the hemicelluloses in the wood cell wall
- Some changes to lignin too
- Reduces number of hydrophilic groups in the wood cell wall

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Wood modification

Lumen filling	Cell wall filling	Cross linking - internal	Cross linking	Reaction with wood polymers	Degradation of cell wall
					

Ormondroyd G, Spear M, Curling S (2015) Proceedings of ICE: Construction and Materials 168(4):187-203

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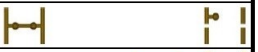
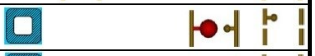
Wood modification

Modification method	Commercial	Principle
Heat treatment	X	
Acetylation (Accoya)	X	
Melamine resin	(X)	
DMDHEU (Belmadur)	X	
Furfurylation(Kebony)	X	
Silicone/Silane	(X)	
oil / wax/ parafins	X	

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Benefits of modified wood

- Greater dimensional stability (high ASE)
- Less strain on paint /surface coatings in service
- Lower equilibrium moisture content (EMC)
- Less likely to exceed the threshold for decay if in use class 3.1 (exterior, covered – i.e. uptake of atmospheric moisture)
- Less likely to exceed threshold for decay in use class 3.2 (exterior, exposed) – if freely drying

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Acetylation process

- Wood is loaded into a specially designed vessel which is suitable for pressure and vacuum
- The vessel is also thermally jacketed and suitable for drying the finished timber after the process
- The acetic anhydride can be introduced under vacuum to maximise penetration of the full plank lengths
- Radiata pine is used, due to high permeability and availability of low-knot content wood
- Some highly permeable hardwoods also suitable

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Acetylation process

- The reaction is done at elevated temperature
- Based on literature values for acetylation, temperature is over 100°C and the modification will be achieved within several hours
- The reagent is fully recovered and recycled into the process, with some waste products (e.g. extractives/ resin acid derivatives) cleaned out before recirculation
- Acetic anhydride grafts acetate moieties onto the wood
- This evolves an equal number of moles of acetic acid
- The acid must be removed from the wood after the reaction – the process is a trade secret, but it is a solvent free system

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Now that's confidence!

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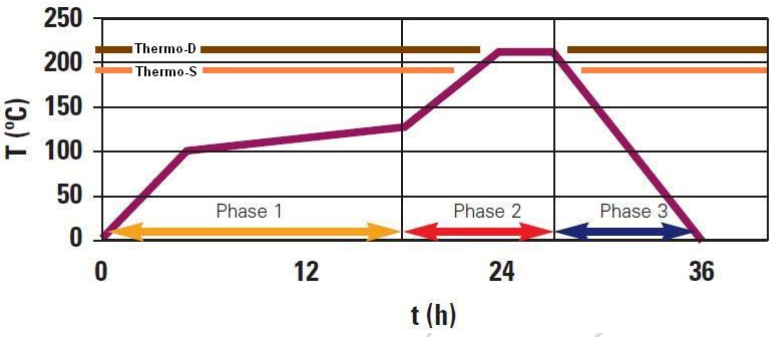
Thermal modification process

- Many technologies on the market, due to parallel developments in Scandinavia, France, Canada, the Netherlands during the 1990s



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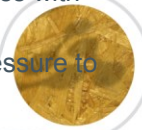
Thermal modification process

- The majority of thermal modifications are performed at atmospheric pressure
- Here the thermal treatment kiln resembles a traditional timber drying kiln, but with adjustments to ensure efficient heating to the high temperatures required, good steam supply and forced air circulation
- Removal of condensation, and control of volatile organic compounds (terpenes and resin acids) as well as condensation products
- The Plato process uses a two-step hydrothermal process with elevated pressure on the first stage
- The WTT system and Fermolin processes use high pressure to allow saturated steam to accelerate the reaction



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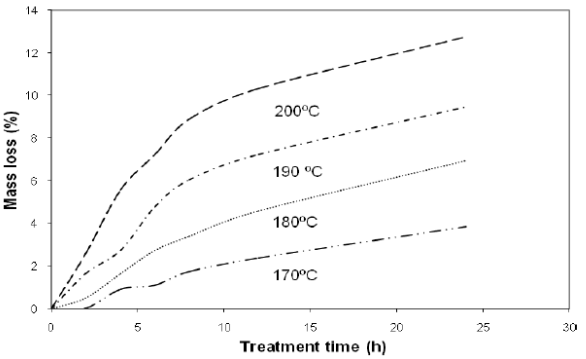
Thermal modification processes

Treatment intensity relates to time and temperature



Esteves and Pereira (2009) Bioresources 4(1):370-404

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Thermal modification

- Input timber – how dry?
- Species – softwoods and hardwoods
- Plank size – a reasonable range of thicknesses
- Mechanical restraint
- Avoiding kilning defects: e.g. case hardening, honeycombing

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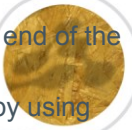
Oil heat treatment

- Often overlooked, or just mentioned as a variation of thermal modification
- Previously by Menzholz
- The system utilises pre-heated wood to rapidly transfer heat into the timber
- But this means it requires a permeable timber
- The reaction under oil alters the reaction of the wood somewhat, due to exclusion of oxygen
- Oil must be removed to a greater or lesser extent at the end of the treatment
- Other variations have looked to cure or dry the oil, e.g. by using polyunsaturated oils to allow oxidative cross linking



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Two very different relationships with water

← Thermally modified wood

Oil heat treated wood ↓

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Furfurylation

- A furfuryl alcohol reagent is mixed with catalyst for this modification process
- Kebonisation requires timber with good permeability
- A pressure treatment process is used to get the liquid mixture fully into the wood structure
- The timber is then dried before a curing process which is conducted at above 100°C
- The treatment liquid is reclaimed and reused on the next cycle
- Weight percent gain can range from 20 to 125%

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Also pretty confident around water!

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Resin impregnation

- Various resin modification systems have been developed and floated on the market
- Often based on phenol formaldehyde or melamine urea formaldehyde, or related products
- Similar to acetylation and furfurylation, this needs highly permeable timbers
- Systems rely on pressure impregnation to maximise resin uptake
- After draining the resin there is a drying phase
- Cure must occur at temperatures well above 100°C, depending on the resin formulation
- Research has optimised the molecular weight of resin oligomer

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Watch this space…

Resin treated wood under development
(A4B CIRP project at Bangor)

Unplaned and planed surfaces