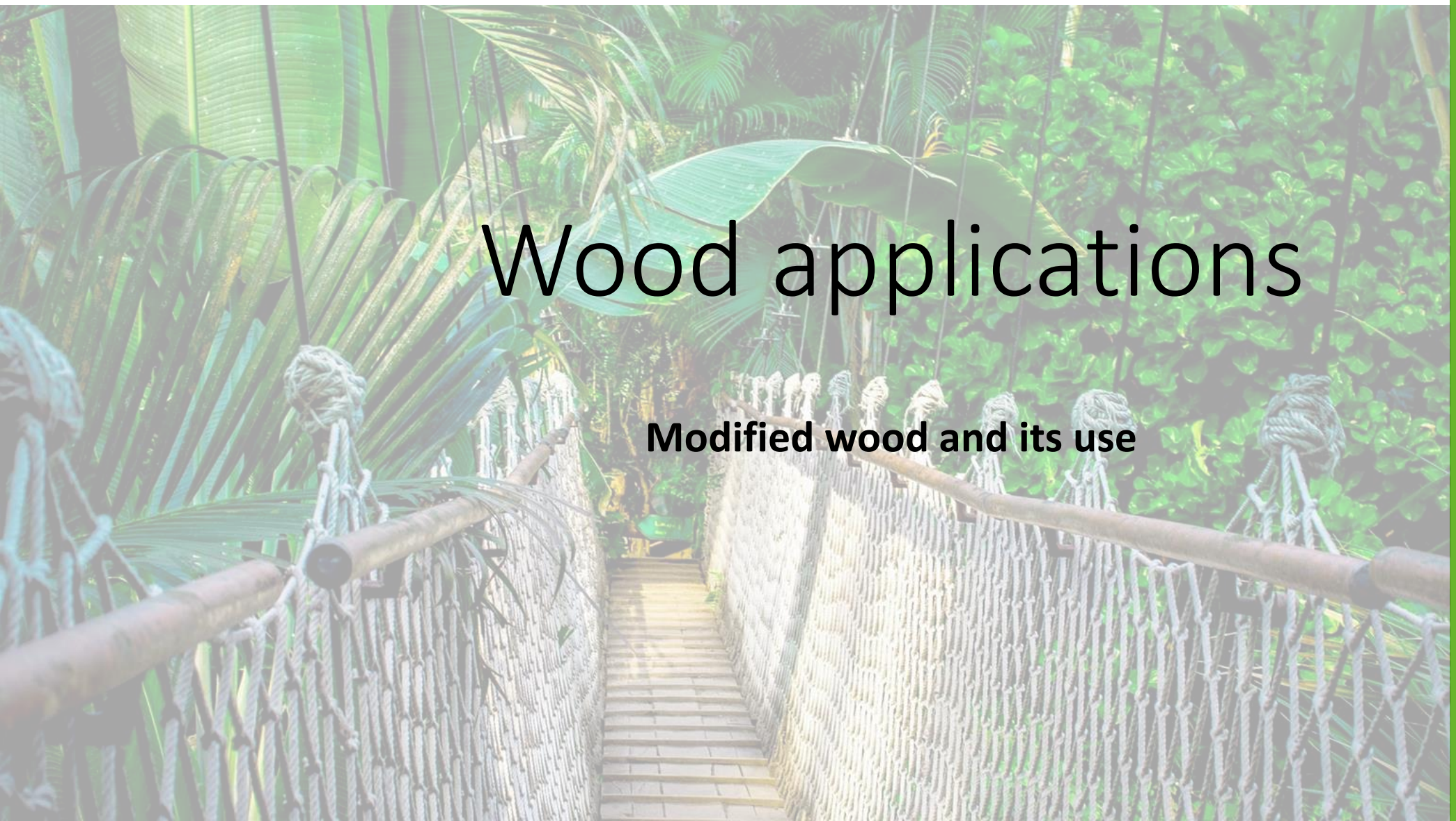
Co-funded by the
Erasmus+ Programme
of the European Union



Wood applications

Modified wood and its use

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- As a result of the thermal modification of wood, the **hygroscopicity of wood decreases in proportion to the loss of mass.**
- Mass loss is mainly caused by the **degradation of hemicelluloses**, the most hydrophilic components in the cell wall.
- Due to thermal modification, **less durable or non-durable woods** (durability class 4 and 5 according to ČSN EN 350) **usually become durable to very durable** (durability class 1 and 2).
- **Longer and harder regimes of thermal modification significantly increase the biological resistance**, mainly against cellulose-forming and lignin-forming fungi.

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- Thermal modification of wood uses the effect **of high temperatures on wood at a certain time and under pre-set conditions** (pressure, temperature, duration, environment, etc.). Currently industrially used thermal modification of wood uses temperatures in the range of **160 – 280 °C**, sometimes, a narrower range of **180 – 260 °C** is mentioned. Temperatures lower than 140 °C cause small, insignificant changes, while temperatures above 300 °C already cause wood degradation, leading to a significant deterioration of its properties.
- The most widely used technologies for the thermal modification of wood include five basic processes: **ThermoWood®** (Finland), **PLATO®** (Netherlands), **OHT** (Germany), **Rétification**, and **Bois Perdue** (France), which are used mostly for industrial production.
- Recently, **newer technologies for the thermal modification** of wood have appeared, such as **WTT** (Denmark), **Huber Holz** (Austria), **Firmolin** (Netherlands), and **Termovuoto** (Italy), which are still used to a lesser extent. **All industrially used thermal treatment technologies differ mainly in thermal modification conditions.**

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- PLATO® process
  - **Hydrothermal treatment** - the wood is stored in a special autoclave, where it is **heated with saturated steam at a pressure of 0.6-0.9 MPa** up to a final **temperature of 150-180 °C**. This temperature is maintained for a certain time depending on the type of wood, the dimensions of the wood and the total volume (**4-5 hours**).
  - **Drying** – wood placed in a drying chamber is slowly **heated and dried to a moisture content of 8-10%** for 5-21 days.
  - **Curing** - the wood is moved to large-capacity chambers, where it is **heated at a temperature of 150-190 °C and atmospheric pressure**. **Wood moisture reaches** a value of **approx. 1%**. The **oxygen content** in the chamber is **maintained at 2% by injecting superheated steam**, which prevents the wood from igniting. The whole process takes **12-16 hours**.
  - **Air-conditioning** – by **slow moistening**, the **moisture content of the wood is adjusted to 3-5%** over the course of 3 days.

- For the production of Plato® Wood, **spruce and frake** are most often used, and to a lesser extent, **pine, fir, poplar and birch.**

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Frake



Spruce



PlatoWood products

PlatoWood application

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- **Oil Heat Treatment (OHT)**
  - The thermal modification takes place in an impregnation container, in which the **wood is stored and then heated to a temperature of 180-220 °C using hot vegetable oil**. Hot oil serves as a h**eat transfer medium** and **prevents access of oxygen**, which triggers unwanted thermo-oxidative reactions.
  - In the wood, **it is necessary to maintain a temperature of around 200°C for 2-4 hours**. Currently, **rapeseed, sunflower, or linseed oil** is **most commonly used.**

- Thermally modified wood by the OHT process is most often produced from **spruce and pine.**
- It does not have the color differences on the surface that are typical for wood modified in an air environment.

OHT application

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- ThermoWood® process
- The **most widely used technology of thermal modification** of wood.
  - The **wood is heated in a humid environment above a temperature of 150 °C for 2-10 hours** to achieve a minimum weight loss of 3%. The modification itself does not use any chemical substance and **takes place only with the help of steam with an oxygen content of 3-5%,** without the use of increased pressure and with an airflow of at least 10 m/s, while the wood must be placed evenly on top of each other and separated by partitions.
  - **The input material can be dried or fresh** (increasing the drying temperature is faster).
  - The method is **applicable for common hard and soft woods**, but the conditions must be set for each wood separately.

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Thermally modified wood

- **Heating and high-temperature drying** – **the temperature** in the chamber **is quickly increased to 100 °C** and then **more slowly to 130 °C** using water vapor or hot air. **Water is removed from the wood during drying**, which has almost zero moisture. The heating and drying time takes **24-48 hours** and depends on the wood species, input humidity, and dimensions of the lumber (mainly thickness).
- **Heat treatment – the temperature in the chamber starts to rise up to the desired value of 180-212 °C**, which is maintained **for 2-3 hours**. **During heat treatment, steam is blown into the chamber**, which is a protective medium against wood ignition and favorably affects the ongoing chemical reactions.
- **Cooling and moiste**ning – immediately **after heat treatment, slow cooling occurs**. **At a temperature of 80 - 90 °C**, water is sprayed in the chamber, which will gradually **increase the moisture content of the wood to a usable level of 4 - 7%.** The chamber opens at a temperature of up to 40 °C to avoid thermal shock and sudden deterioration of the properties of the modified wood. The **entire stage takes an average of 5-15 hours**, depending on the type of wood used and the final temperature.

ThermoWood application

ThermoWood application

ThermoWood application

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Chemically modified wood

- Chemical modification of wood **is based on the action and reactions of chemical substances with wood components, while new chemical bonds are created.**
- **A wide range of chemicals are used**, such as the oldest **CCA or ammonia**, but the most significant representation is in
- **Ammonia acts as a suitable plasticizer** (especially in liquid form), which has been **used in the furniture industry for decades**.
- The change in wood density is small, so there are no significant changes in mechanical properties. **The disadvantage of using ammonia is an increase in drying and swelling**, as well as color changes in the wood. currently acetic anhydride.
- **Impregnation can also be included under chemical modification.**

Co-funded by the
Erasmus+ Programme
of the European Union

The tank vacuum pressure process

Impregnated wood

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Chemically modified wood

- **Acetylated wood** is solid **wood treated chemically using acetylation**. **ACCOYA® Wood is the most widespread representative of acetylated wood.**
- **ACCOYA Wood®** is a material where the **solid wood of conifers** (almost exclusively Monterey pine - Pinus radiata) **is chemically modified by acetylation using acetic anhydrides.**
- AccoyaWood has **increased durability due to limited water absorption by up to 80%.** This fact **increases not only dimensional stability** (equilibrium moisture is 3-5%), but also **eliminates the occurrence and action of rot and mold.**
- **Acetylated wood is the main competitor of thermally modified wood.**
- Acetylated wood is used as a material for **wall cladding, patio flooring, windows, and doors or for exterior structural elements** such as **outdoor flooring** and **cladding**, **bridges and boats**, **water features.**

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Impreg

- Impreg is a **material created by combining veneers and phenoplasts**, similar to plywood. It consists of a **set of veneers impregnated with phenolic resins**. Individual **veneers are soaked in resins at normal temperature and pressure. After saturating the veneers** with resins, these veneers **are dried and hardened using an elevated temperature of 160-180 °C.** Subsequently, the veneers are **glued into thicker boards under low pressure.**
- Impreg has **good dimensional stability and is resistant to moisture** (25-30% less drying and swelling) **and temperature** (higher thermal insulation properties). It is also **resistant to rot, insects, acids, and electricity.** It has a **15-20% higher density than solid wood or plywood.**
- It is used for creating **sculptures, models, and templates for casting plastic materials, transformer boxes, distribution boxes,** etc.

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Compreg

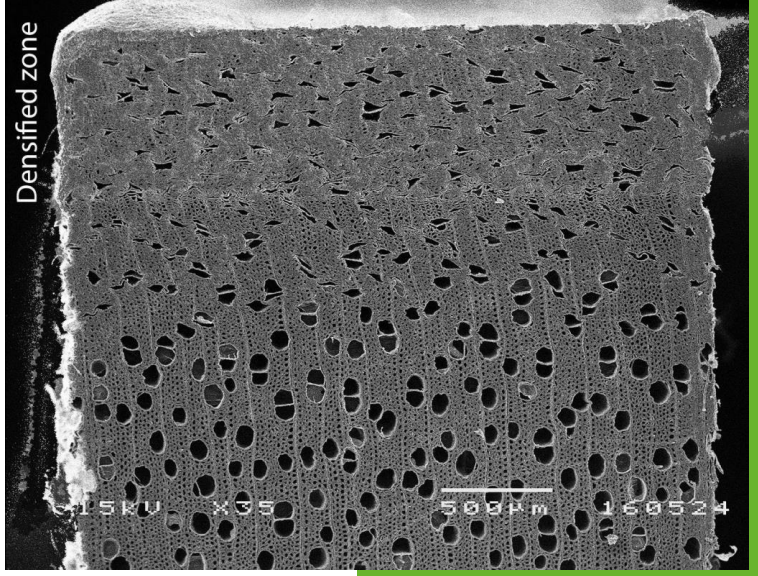
- Compreg is a **material made up of veneers and phenoplasts like Impreg**. **The veneers are soaked and impregnated with phenol-formaldehyde resins**, which are only in the liquid phase in the cell walls. Then the **set of veneers is pressed under extreme pressure of up to 7-20 MPa**, which **leads to densification of the veneers**. Subsequently, **at high temperatures (approx. 160 °C), the resin is cured.**
- The **orientation of the veneers can be transverse** (the direction of the fibers of adjacent veneers is perpendicular to each other) **or parallel** with a certain number of transversely oriented veneers.
- **Veneers with a thickness of 0.6 – 2 mm are used from deciduous trees** (most often beech, sometimes birch) or exotic trees.
- **Compreg is intended for exterior applications**. It is also s**uitable for** the production of **templates, jigs and knife handles.** The **thickness of Compreg is from 5 – 120 mm**. The **density ranges from 750 to 1400 kg/m3** depending on the degree of densification.

Compreg application

Compreg application

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use



Mechanically modified wood

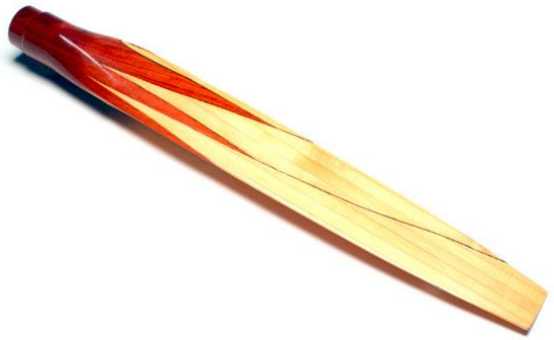
- **Surface (thickness) densification** – the action of **mechanical forces in one direction on the surface of the boards**, which are **densified by up to 50% of the original thickness**. Materials modified in this way are used **to produce flooring, stair treads.** Surface densification is **also used for veneer materials similar to plywood pressed under high pressure and temperature** (but without prior plasticization) **using UF or PF resins**, where individual veneers are densified.
- **Volumetric densification** – the action of mechanical **forces in all three directions** on wood, **which is densification in the entire cross-section**. It is **used to a limited extent**.
- **Longitudinal densification** – the effect of mechanical **forces in the longitudinal direction** (in the direction of the fibers) on the wood, which is densified by this (**shortened by approx. 20%).** This method is **used for subsequent so-called cold bending**, with which it is possible to achieve complicated shapes and bends.

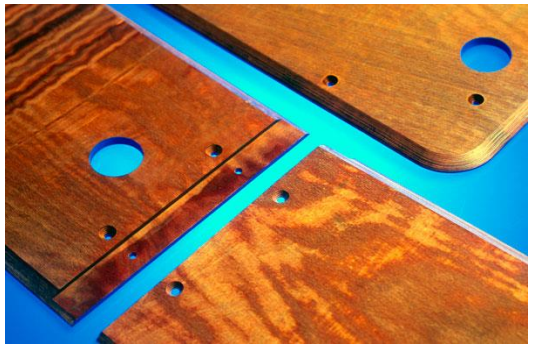
Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Layered densified materials

- They are **materials made up of veneers, the composition of which is very similar to Compreg but without their impregnation with resins. Mostly beech veneers are coated with a thin film of synthetic resins and assembled into a set.** Then the set of veneers is **pressed under extreme pressure of up to 10-20 MPa and high temperature**, which leads to densification of the veneers. **The orientation of the veneers can be transverse** (the direction of the fibers of adjacent veneers is perpendicular to each other) **or parallel** according to the use and the required strength.
- **Production of stencils and parts for the textile industry**, for **pads and parts of aircraft** (propellers, partitions), and **transport vehicles.**





Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Cold-bend hardwood

- It is **created by longitudinal densification and subsequent bending of plasticized grown wood**. The principle was invented in Denmark for bending wood into complicated shapes with small rounding radius. Hardwoods are suitable for bending. **The wood of exotic species, artificially dried lumber, and conifers are not used.** The production of the material consists of three steps:
  - **Plasticization –** wooden prisms (most often 40 × 40 mm or 45 × 45 mm) of suitable quality (without deflection of fibers and knots) with a moisture content of 20-25% are plasticized in an autoclave using steam at a temperature of up to 100 °C.
  - **Longitudinal densification** – immediately after plasticizing, the chips are inserted into a particular machine with a V-shaped matrix, which is longitudinally compressed by 20% of their original length (approx. 5% return after release), and the fibers are stacked like an accordion. Thickening takes 8-10 minutes,
  - **Bending –** densified wood can be bent in multiple planes without additional heat in bending machines or by hand with jigs. Then the wood is dried to preserve its new shape.
- The mechanical properties of longitudinally densified wood are changed; at least the bending strength is lower by approx—10%. Hardness and compressive strength are increased by approx—10-15%.
- The material is **used to make furniture, musical instruments, interior elements, art objects, ships and boats, round structural elements, etc**. It should **not be used outdoors** because of the humidity and temperature change, and it is impossible to maintain the bent shape.

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

Bendywood®

- Bendywood® is most often **produced from beech** as planks or prisms with dimensions of 120 × 120 mm, 100 × 120 mm and 60 × 120 mm or as a round bar with a diameter of ø 40 – 45 mm and a length of 2.2 m.

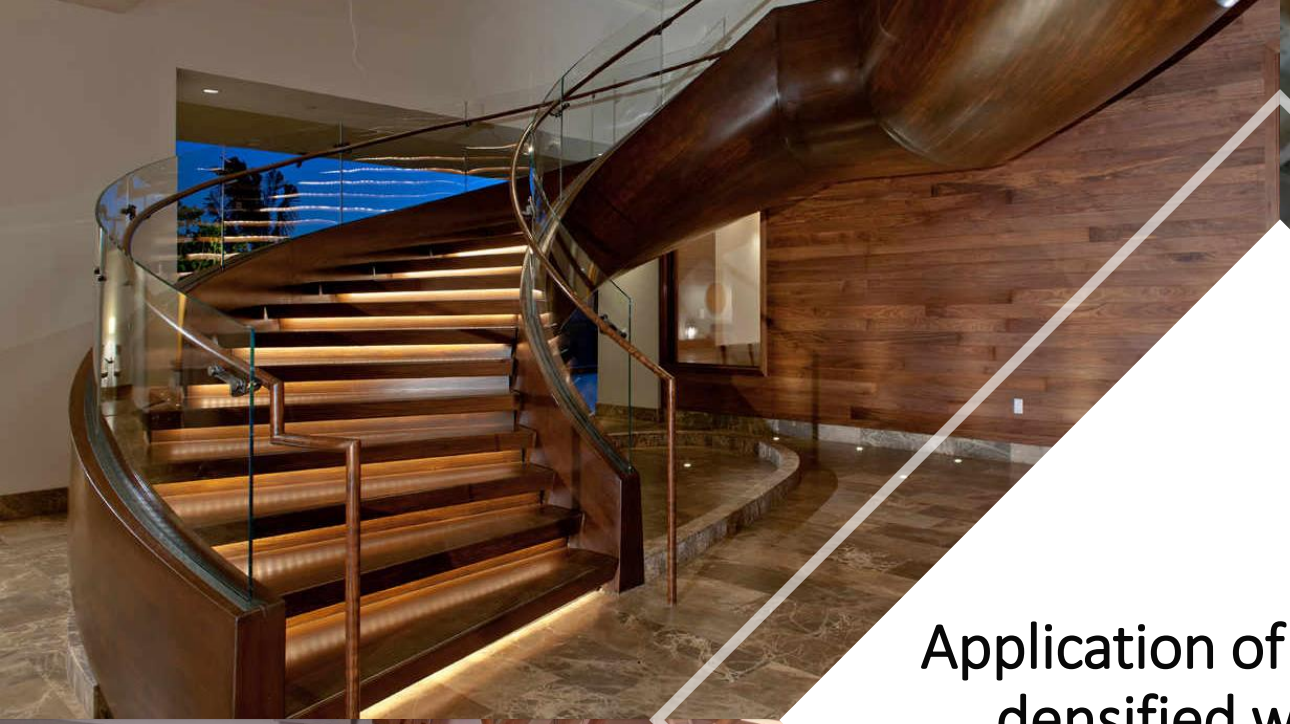
Technical data	Bendywood® beech	Normal beech
Density (kg/m³)	**890**	730
Compression (%)	**20**	0
Modul of elasticity (N/mm²) at a moisture content of about 12%	**3900**	11000
Elasticity limit (N/mm²)	**31**	59
Breaking load (N/mm²)	**102**	74
Bending ratio (= thickness/tightest radius)	**1/10**	1/60

Co-funded by the
Erasmus+ Programme
of the European Union

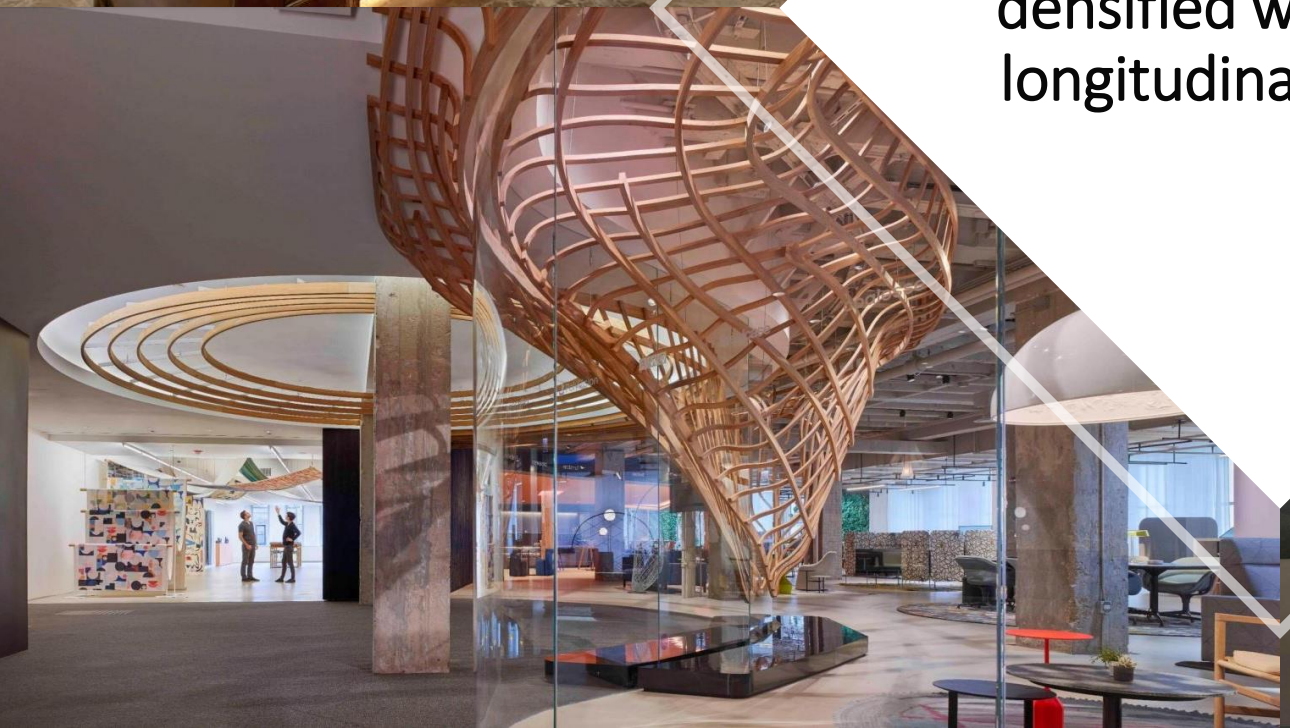
Application of mechanically densified wood in the longitudinal direction

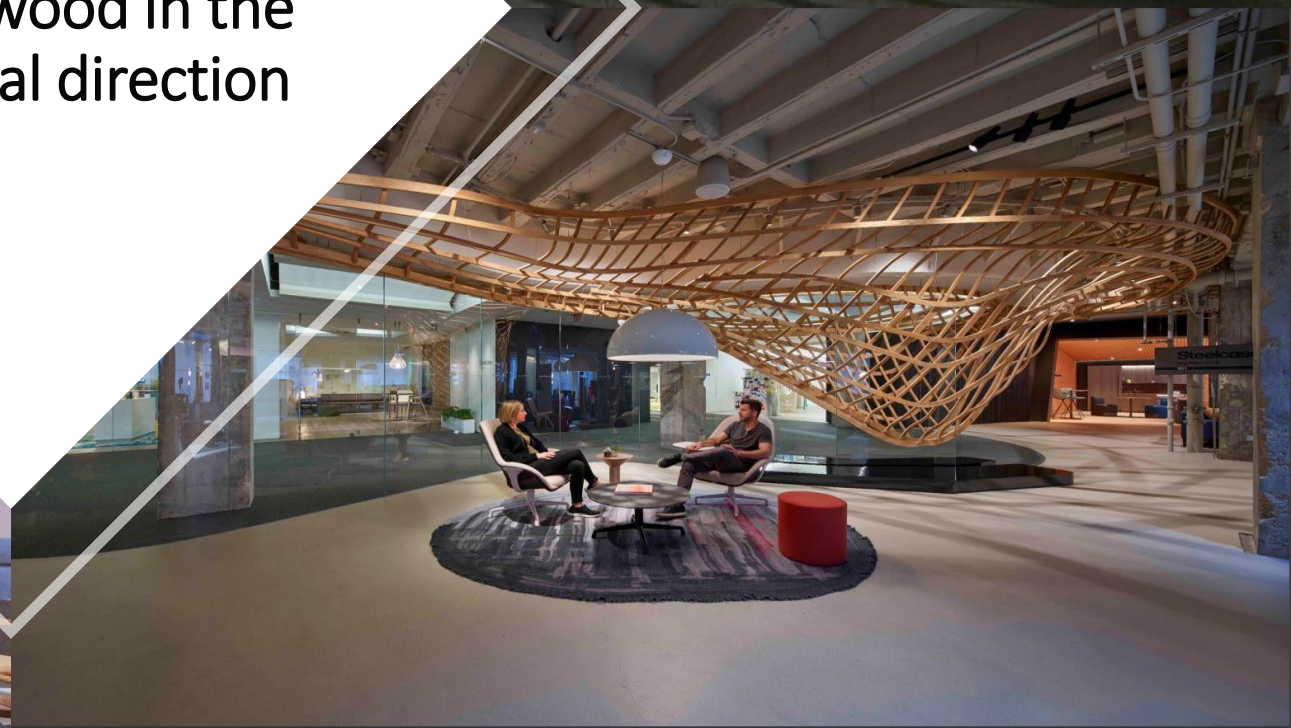
Aplikace mechanicky zkušťovaného dřeva v podélném směru

Application of mechanically densified wood in the longitudinal direction

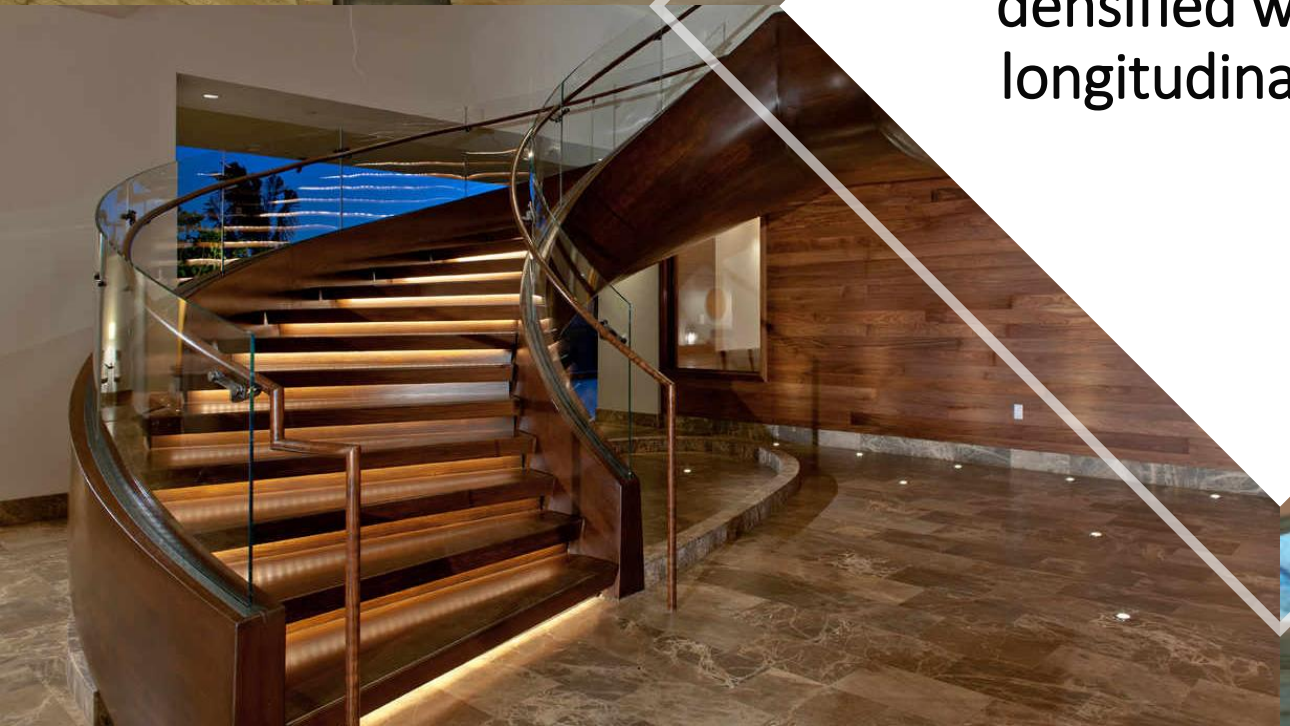


Application of mechanically densified wood in the longitudinal direction



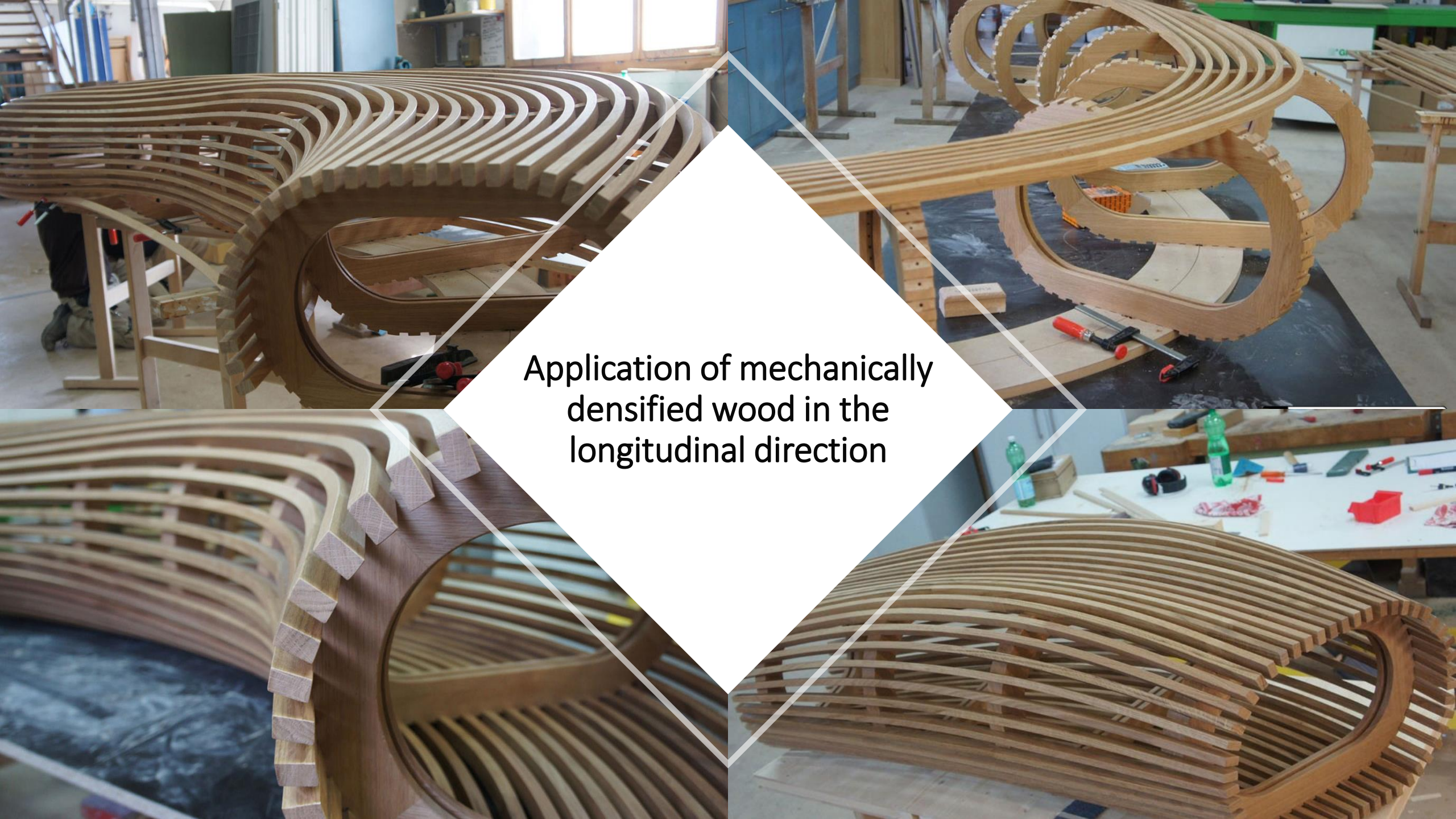


Application of mechanically densified wood in the longitudinal direction

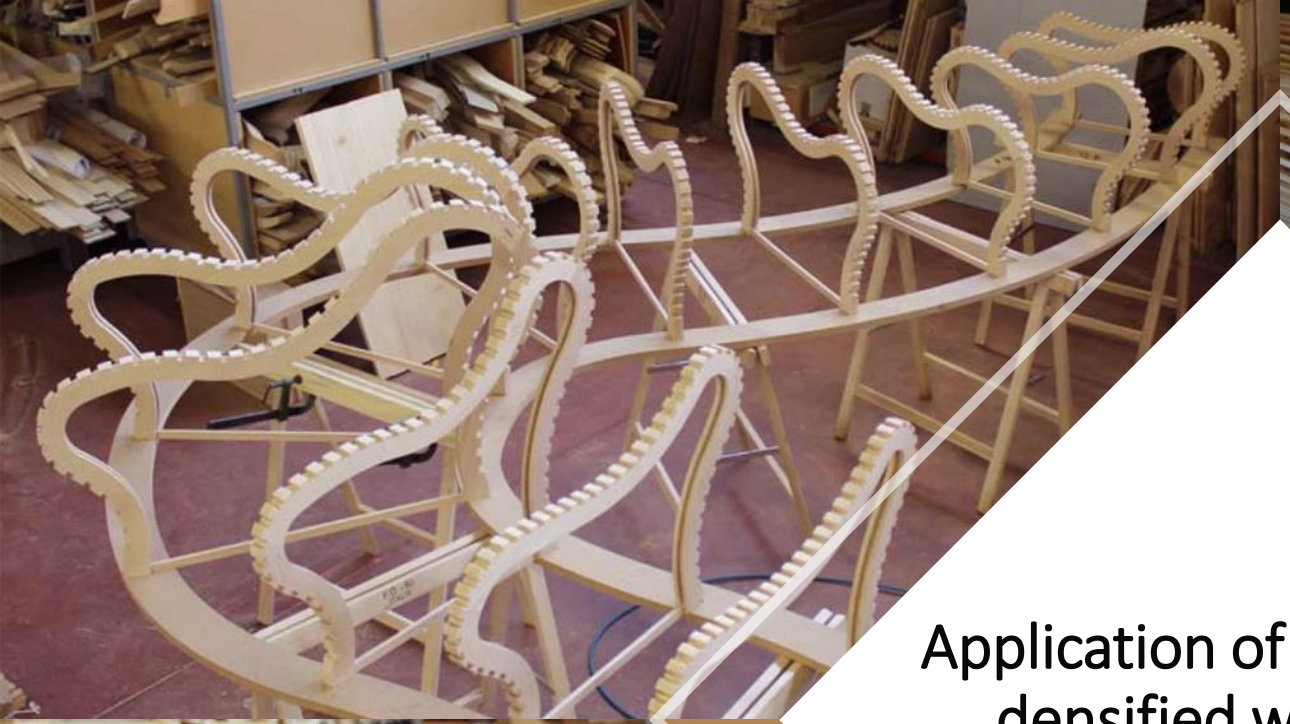


Application of mechanically densified wood in the longitudinal direction

Application of mechanically densified wood in the longitudinal direction



Application of mechanically densified wood in the longitudinal direction



Application of mechanically densified wood in the longitudinal direction

Application of mechanically densified wood in the longitudinal direction

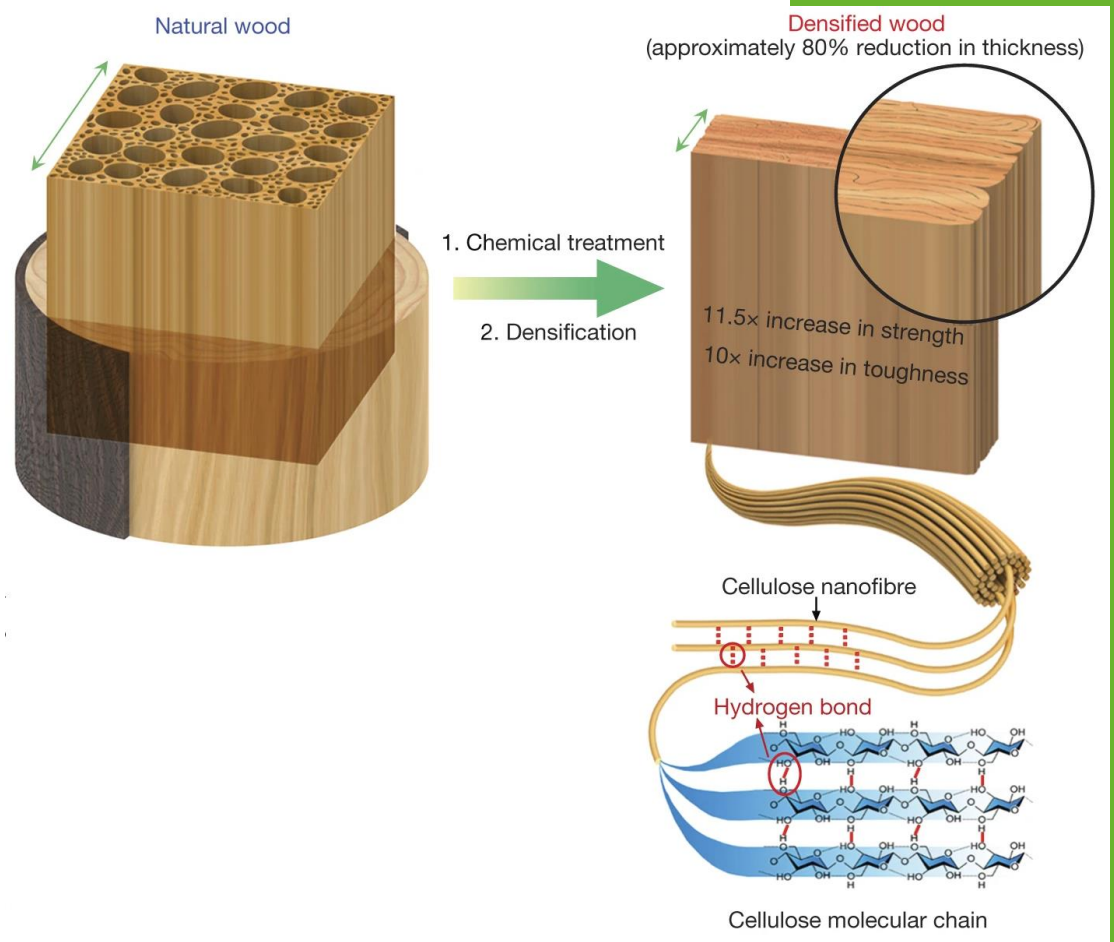
Application of mechanically densified wood in the longitudinal direction

Co-funded by the
Erasmus+ Programme
of the European Union

Modified wood and its use

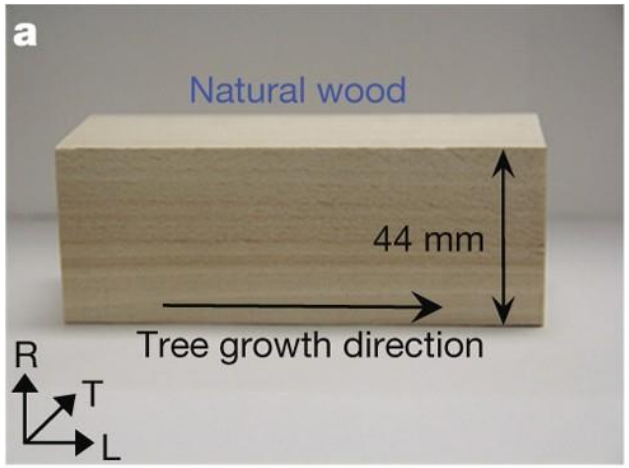
MettleWood

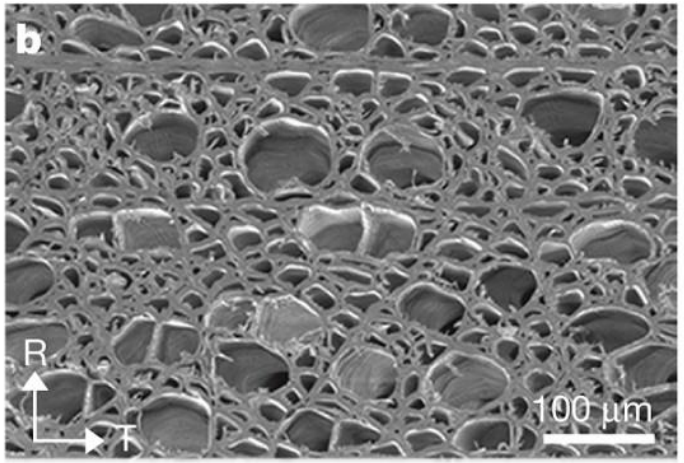
- Solid wood material that is **chemically modified and then compressed by 80% of its original thickness**, resulting in complete densification.
- Solid **wood is first boiled in a NaOH/Na2SO3 solution** for about 7 hours, which makes it **more porous and flexible**. Subsequently, it is **densified perpendicular to the direction of the fibers at a pressure of 5 MPa and a temperature of 100 °C.** The process involves the partial removal of hemicelluloses and lignin.
- Material **for construction, the automotive industry, and the materials sector** offers significant advantages over commonly used materials.

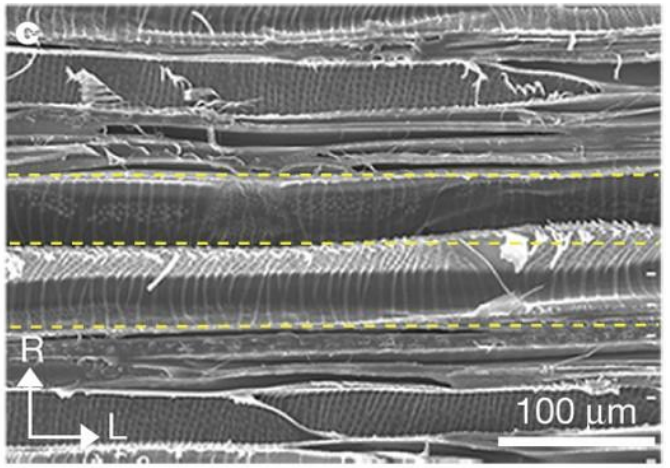


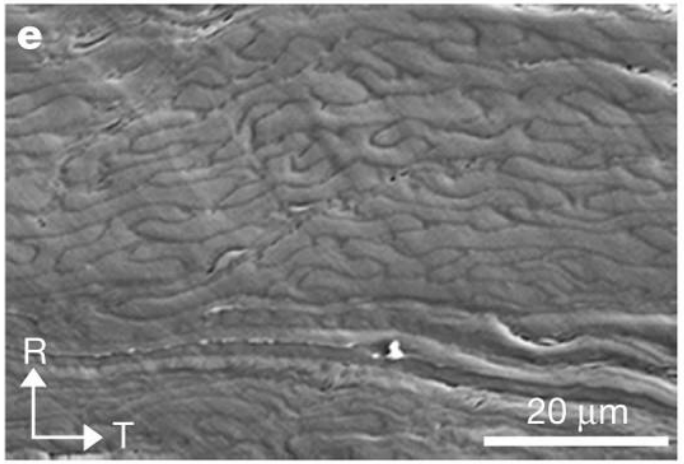
Co-funded by the
Erasmus+ Programme
of the European Union

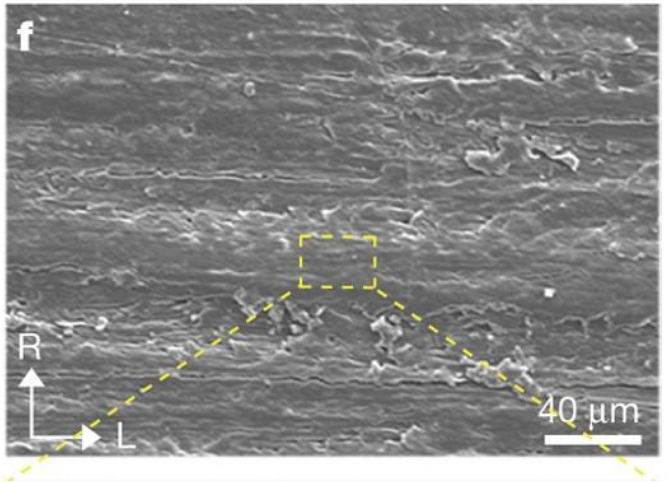
Modified wood and its use







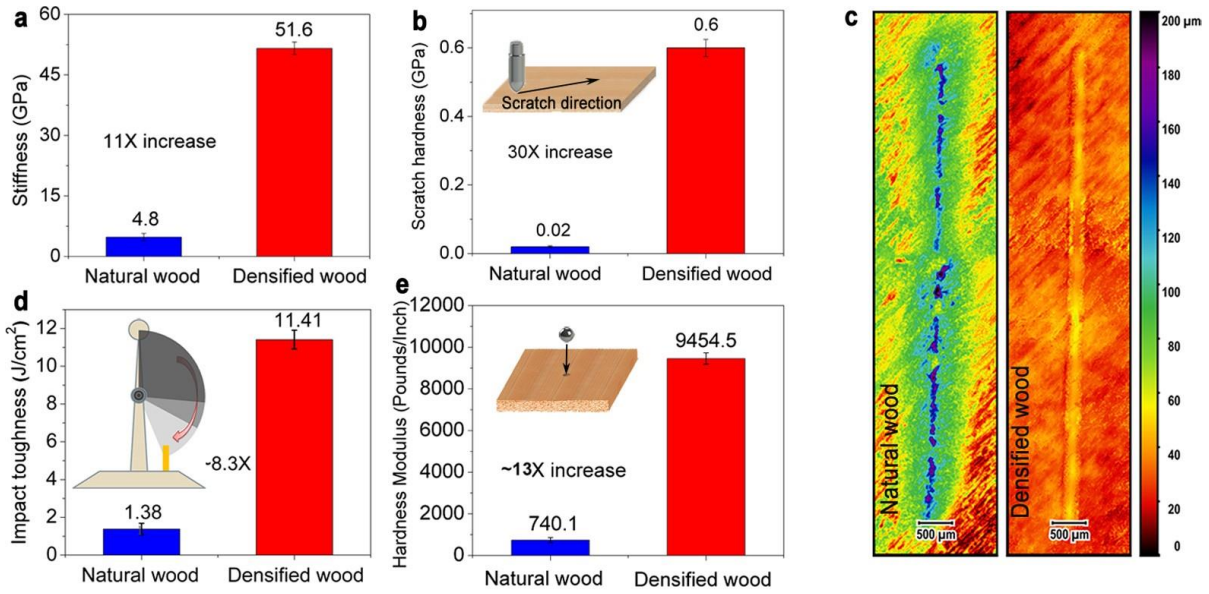


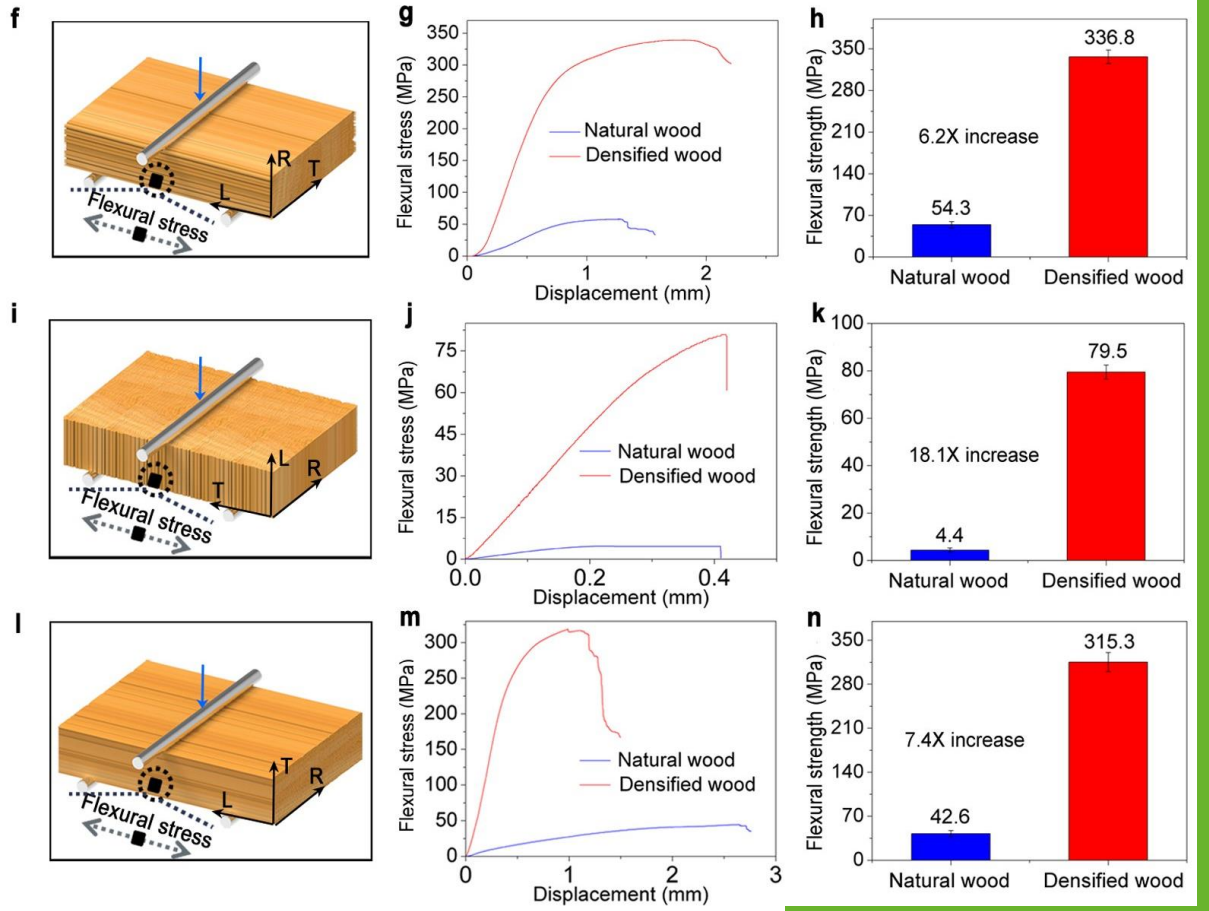


Co-funded by the
Erasmus+ Programme
of the European Union

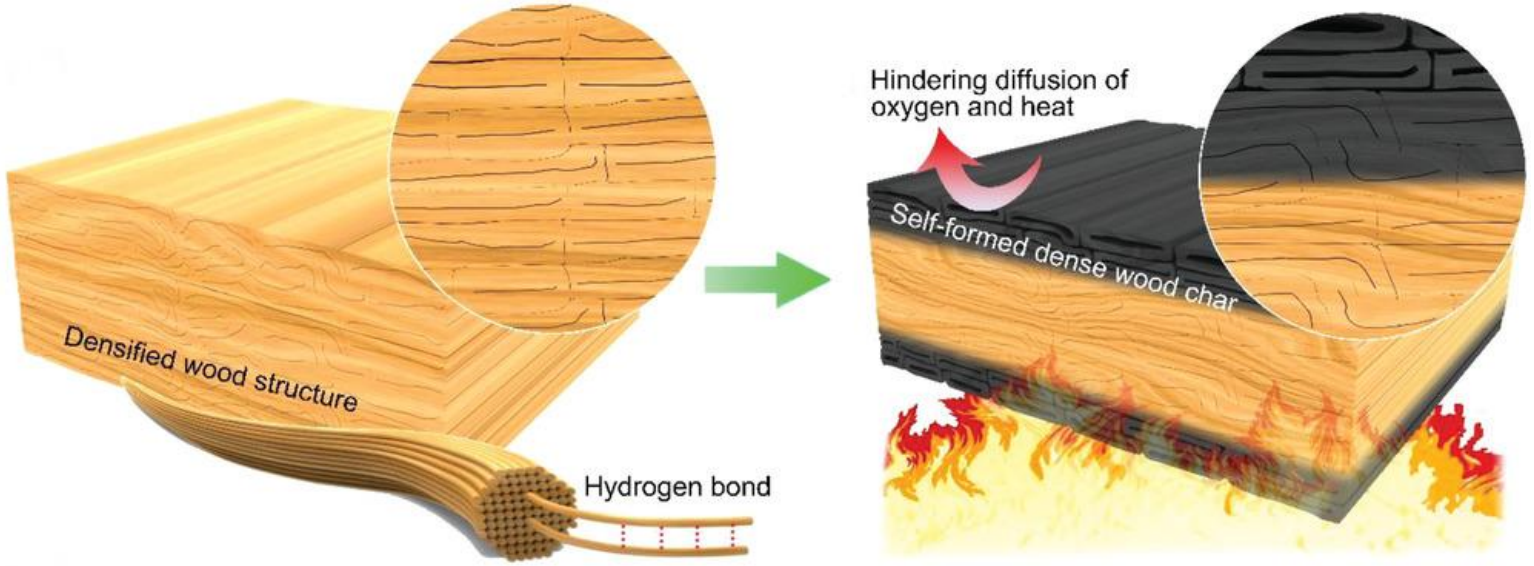
FRAME

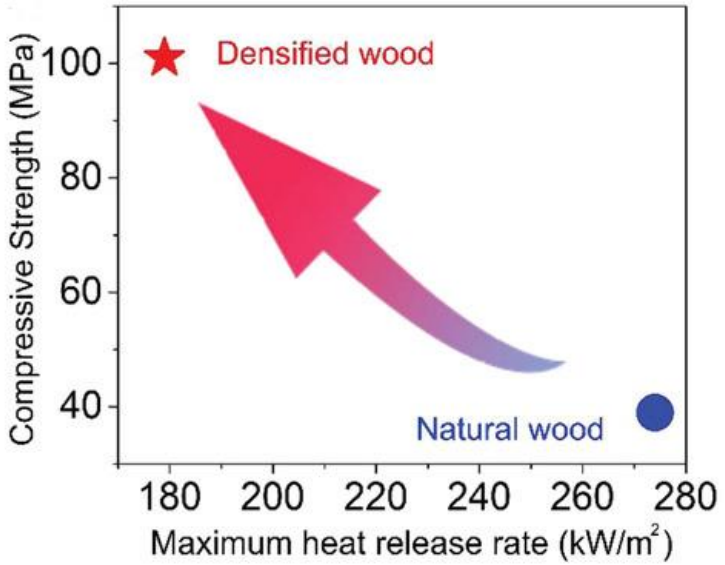
Modified wood and its use





Co-funded by the
Erasmus+ Programme
of the European Union





Densified wood *vs.* **Natural wood**

- Dense char layer
- No fire retardant
- Long ignition time
- Low heat release rate
- High compressive strength