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WOOD in CIRCLE

Wood as building material.
From wood to construction material

Girts Zarins, RTU

March 15th 2022

VILNIUS TECH
RIGA TECHNICAL UNIVERSITY
HAMK HÄMEEN AMMATTIKORKEAKOULU HÄME UNIVERSITY OF APPLIED SCIENCES
UNIVERSITÀ DEGLI STUDI DI PALERMO
LAUREA

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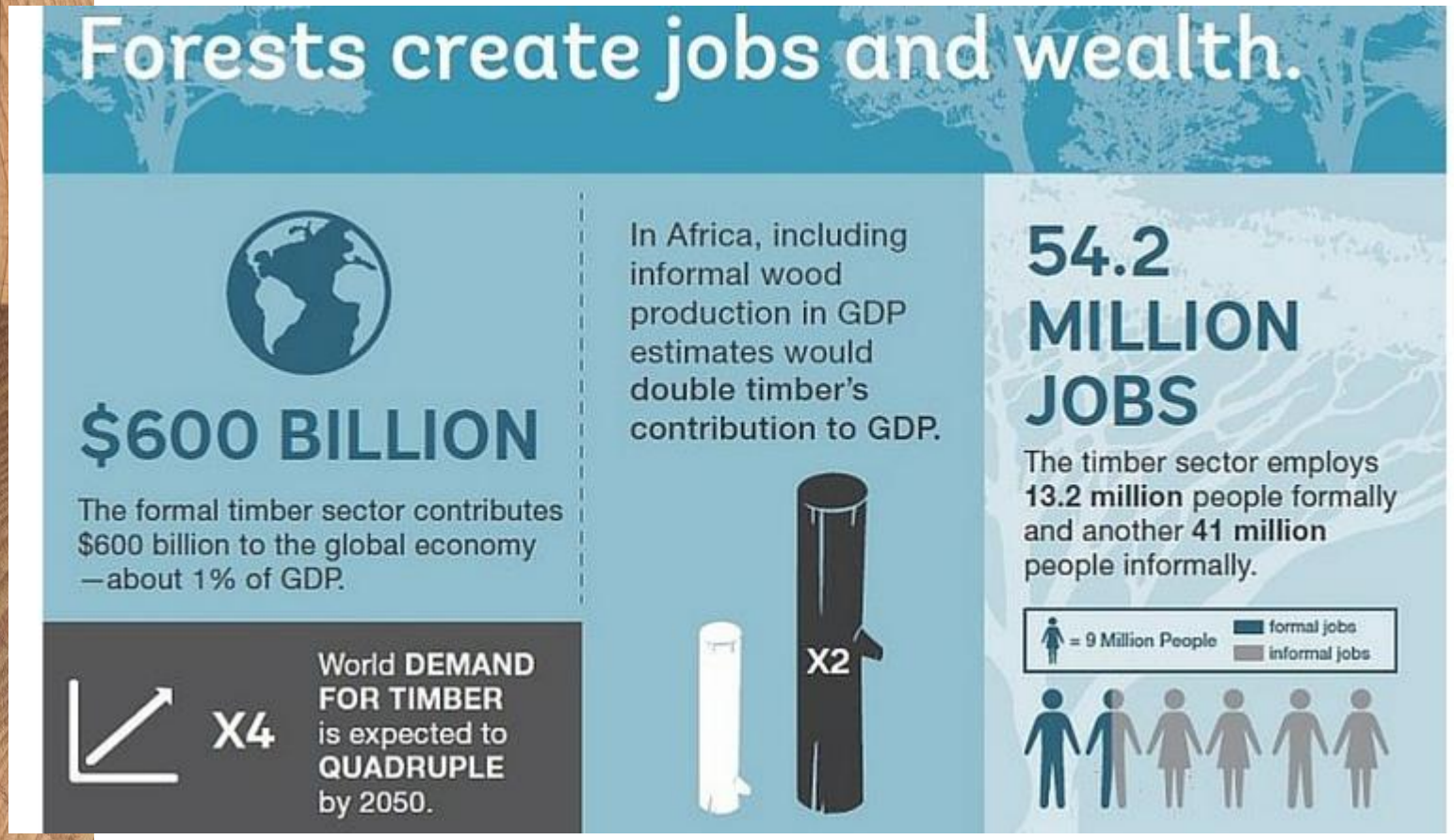
Economic aspect



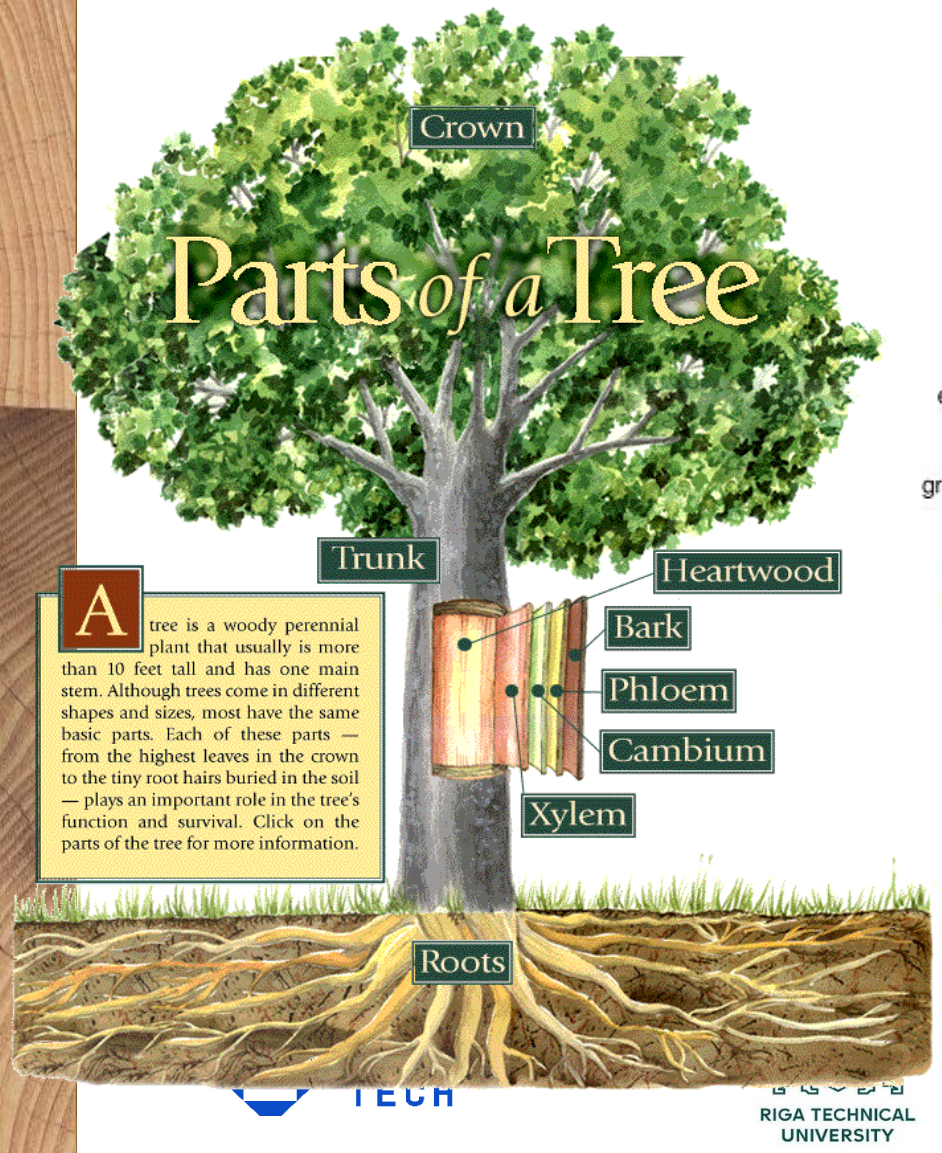
Forests generate wealth and millions of jobs. The formal timber sector employs more than 13.2 million people. It also produces more than 5,000 types of wood-based products and generates a gross value added of over $600 billion (≈EUR 493 billion) each year.

Including the informal sector in GDP calculations could double the contribution of the timber sector and quadruple the number of related full-time jobs.

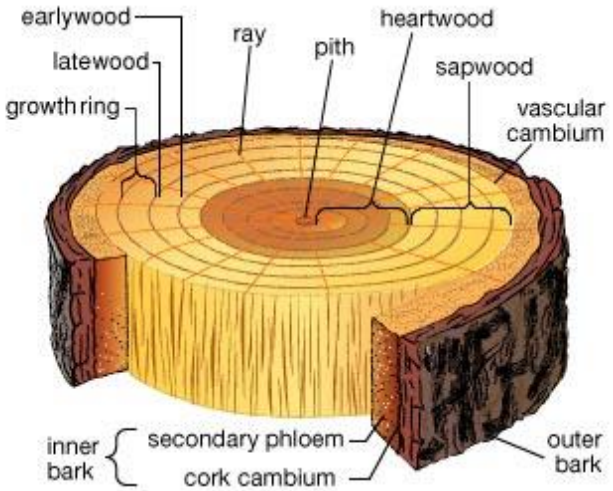
Inputs of timber sector to global economy (The World Bank, n.d.).

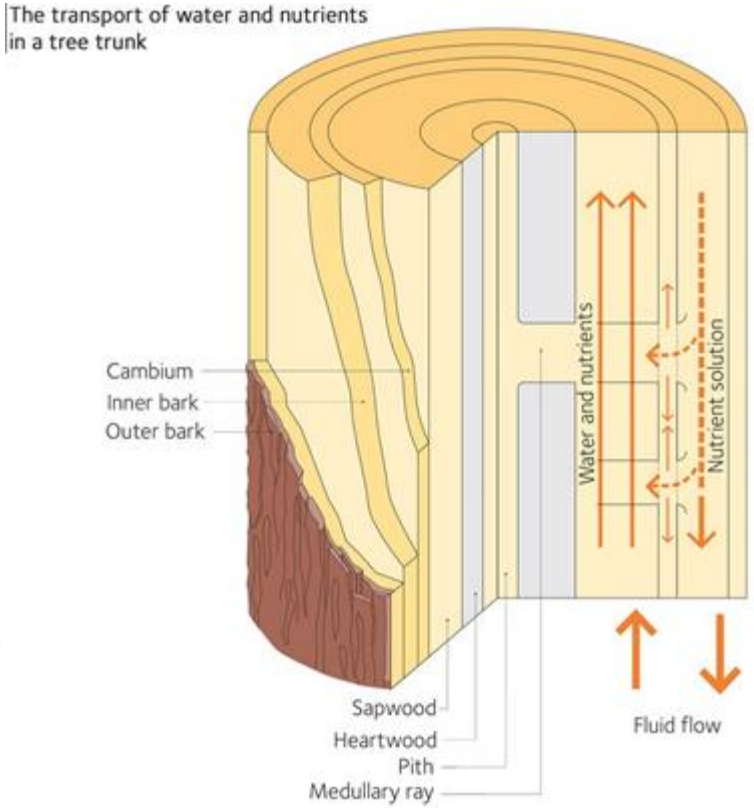
Structure of Timber

of the European Union



A tree can be divided into three parts – crown (branches and leaves), trunk and roots





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LAU REA

https://www.swedishwood.com

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Economic aspect

In terms of construction, from the economic perspective, timber products are a cost-effective solution since they are structurally efficient, light weight, easy and quick to install at the construction site

Higher speed of assembly is also linked to reduced labor hours and project cost:

- Wood can be locally sourced and is usually less expensive than alternative building materials.
- Wood building systems typically cost less to install. Wood is readily available and tends to be delivered quickly.
- Faster construction schedules help to keep costs down. Because wood is often readily available, adaptable and easy to use, construction is faster.
- Contractors can reduce labor and material costs with panelizing, the process of assembling roof sections on the ground and then lifting them into place.
- Using wood can save significantly on construction costs. Woodworks.org offers a cost calculator to help builders estimate cost savings from building with wood, taking into account numerous variables like material costs, speed of construction and availability of labor.

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Environmental aspect

Wood is the only renewable construction material that requires very little energy for its processing. By nature, wood is composed of **carbon** that is **captured** from the atmosphere **during** tree **growth**.

As a rule of thumb, the tree 'consumes' the 1.6–1.8 kg CO2 per 1 kg of wood it forms.

When wood is part of the construction, the building works as carbon sink.

Steel and concrete production is responsible for 9 % and 5 % of the world's total fossil energy consumption.

For the construction of Moholt 50 in Norway, approx. 5600 m3 or approx. 2240 tons of solid wood, if we assume a density of 400 kg/m3, was used. The construction resulted in a storage of well 3500 tons of CO2 – or equivalent to almost 2000 average cars annual CO2 emissions at a driving requirement of 15,000 km/year (InnoBYG, 2017).

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HISTORY OF WOODEN CONSTRUCTION: Contemporary wooden buildings

Chilean Pavillion at Expo Milan 2015, by Cristián Undurraga. Copyright: Arauco.

Mjøstårnet (18 stories), the tallest timber-frame building in the world, by Voll Arkitekter

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Timber Logs in Forest

Forestry covers

- Planning and managing forest
- Cut trees
- Brought to transportation place

Transforming wood into timber (Sawmill)

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Main Structural Features of Tree Trunk

- From outside to inside:
  - Bark
  - Cambium (very thin layer) - location of wood growth
  - Sapwood (lighter) – transpo the sap
  - Heartwood (darker) – provides structural support
  - Pith – center stem
  - Rays
  - Annual rings

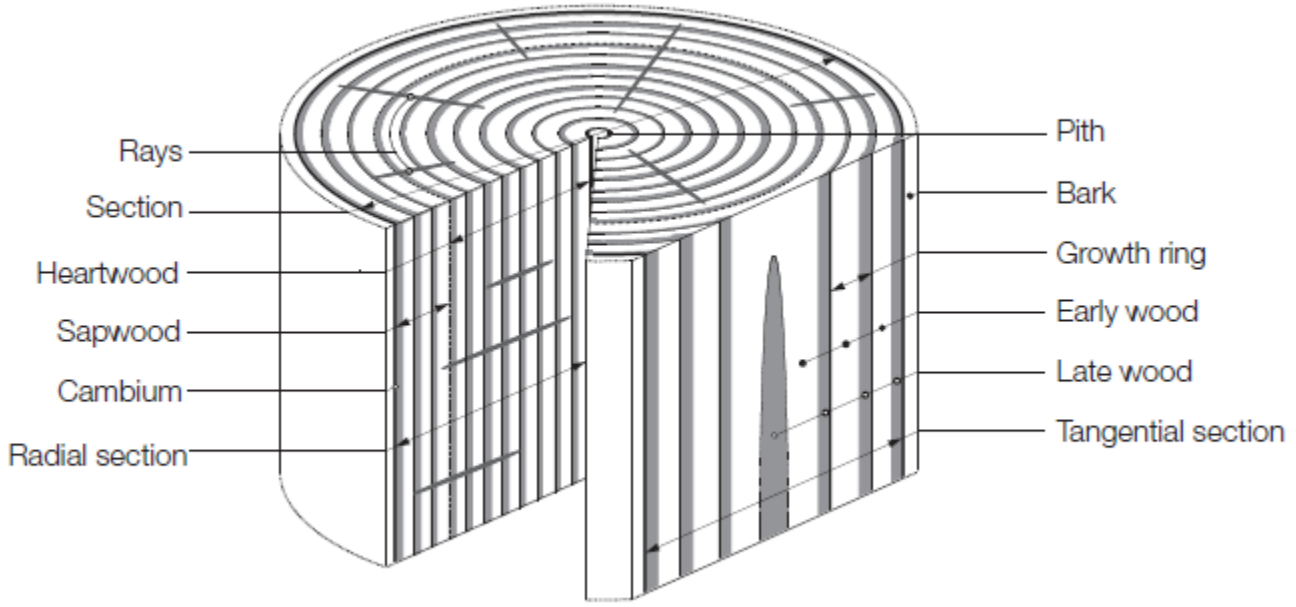

Fig. 1: Section through tree trunk

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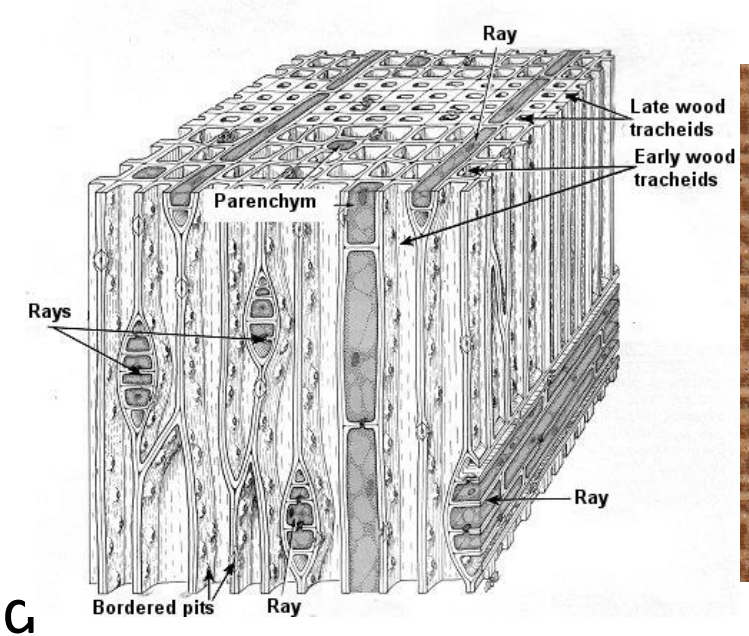
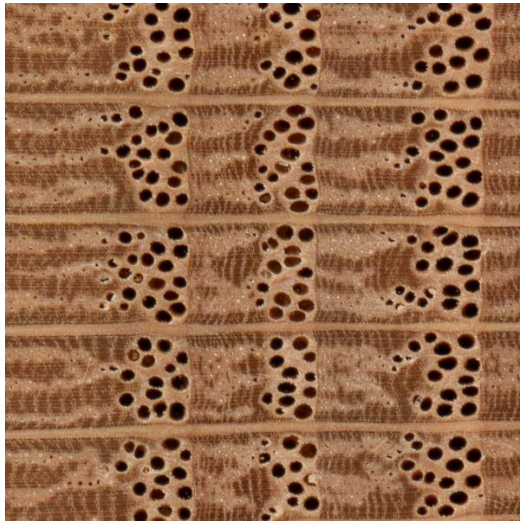
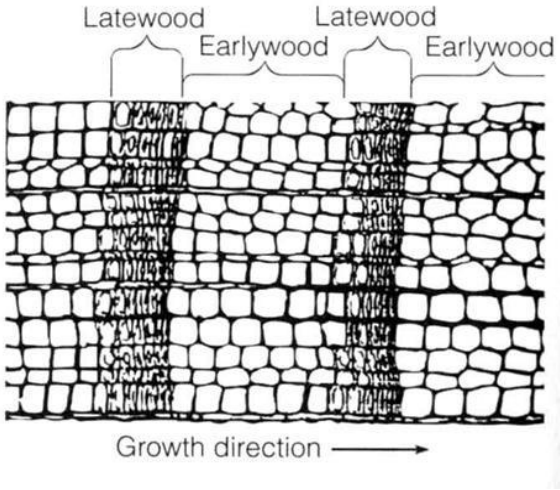
Structure of Timber

- Each annual ring is composed of:
  - **Earlywood** (light ring): rapid spring growth of hollow thin-walled cells
  - **Latewood** (dark ring): dense summer growth of thick-walled cells which are much harder & stronger







Sources:

Structure of Timber

Wood is a natural composite built up of mainly three elements; **50 percent carbon, 6 percent hydrogen and 44 percent oxygen** in the form of cellulose, hemicellulose and lignin. (Species/location)

Nordic softwood species have approximately the proportions 40 – 45 percent cellulose, 25 – 30 percent hemicellulose and 25 – 35 percent lignin.

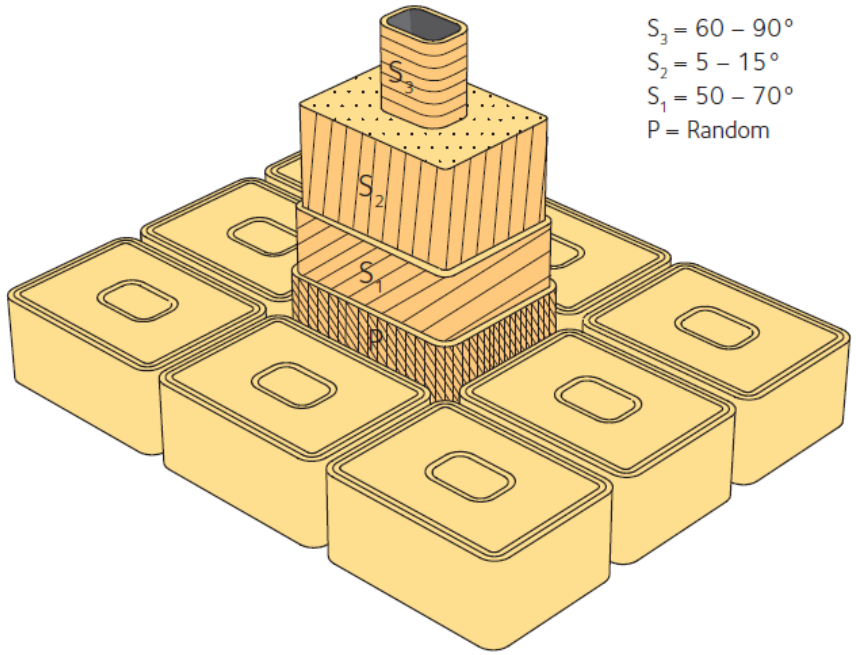
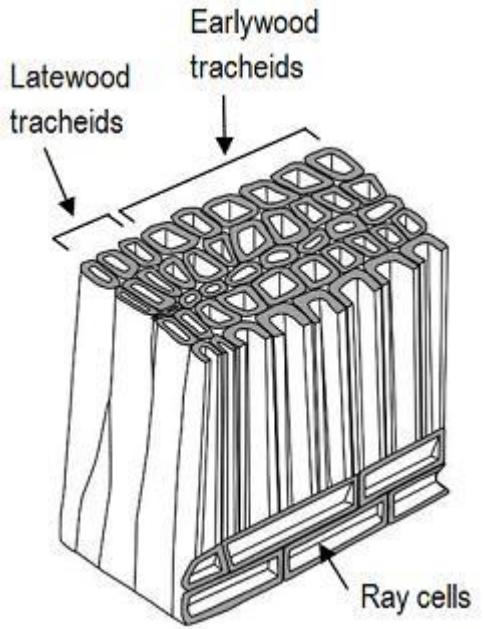


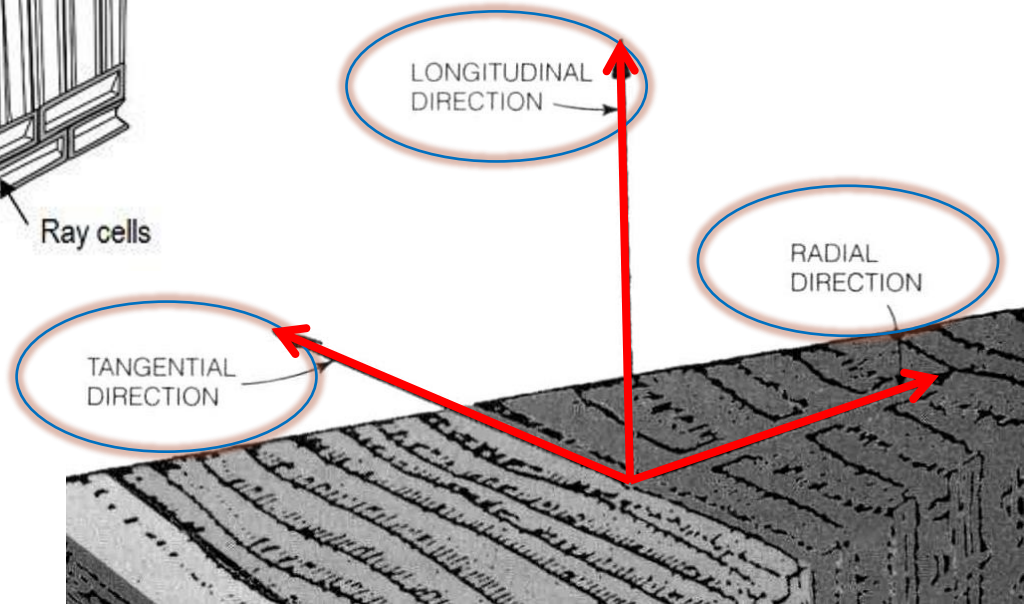
Figure 2.5: The structure of a wood cell. The figure shows the cell wall constructed of 4 layers around the central cell cavity. Typical microfibril angle in these layers is given in the figure, Hoffmeyer (1995).

- Technical properties of same tree species differ for diffrerent growth conditions
- In tropical countries, where trees grow throughout the year, a tree produces wood cells that are essentially uniform.
- The age of a tree may be determined by counting its growth rings.

Anisotropic Nature of Wood

- Longitudinal
  - parallel to the long axis (grain)
  - strongest and least shrinkage
- Radial
  - perpendicular to the growth rings (out from center)
- Tangential
  - tangent to the growth rings
  - weakest and most shrinkage





Directions influence strength, modulus, thermal expansion, conductivity, shrinkage, etc.

Sources:

Wood physics

Wood physics, a key element of wood sciences in general, draws on findings from wood chemistry, wood anatomy and biology, as well as classical chemistry, physics and mechanics and can be defined as the “Science of physical-mechanical properties of wood and wood-based materials”.

Fields of wood physics meriting further discussion include:

- how wood behaves when exposed to moisture,
- wood density
- the rheological (viscoelastic) properties of the wood
- thermal properties
- acoustics and noise-abatements
- behavior in fire

Wood is a cellular material of **biological origin**. Even though it is all around us, it isn’t as simple as we often think. One definition of wood is that it is a hygroscopic, anisotropic material of biological origin.

Hygroscopic - it releases and absorbs moisture from the atmosphere until achieving an equilibrium with the water vapor pressure of the surrounding air.
Anisotropic - its structure and properties vary in different directions.

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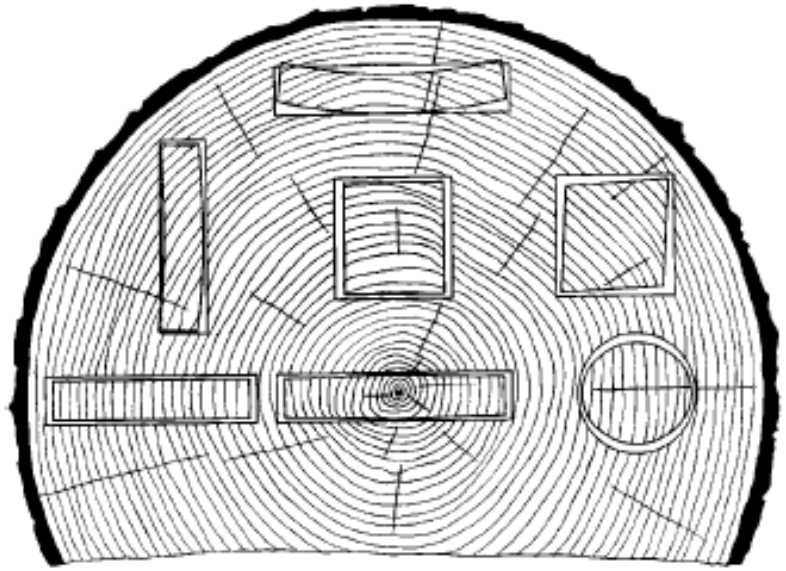
Wood production

Production Steps:

1. Harvesting
2. Sawing
3. Seasoning (drying)
4. Surfacing (Planing) (optional)
5. Grading
6. Preservative Treating (optional)

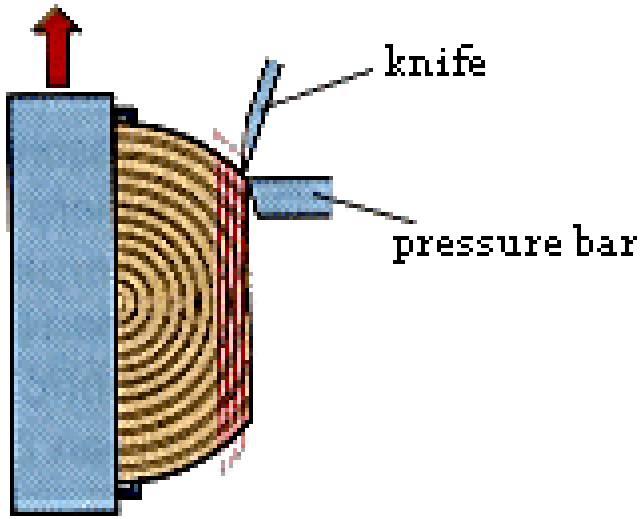
Defects in timber

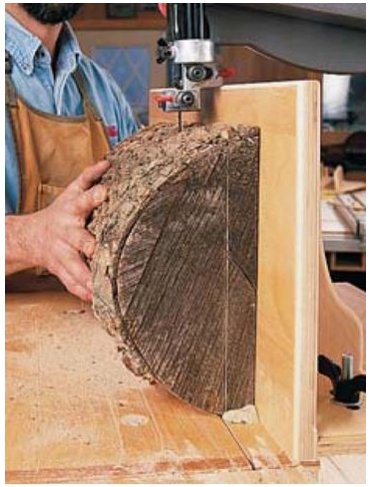
- Owing to the fact that wood is a material which is naturally occurring, there are many defects which are introduced during the growing period and during the conversion and seasoning process.
- Any of these defects ca cause trouble in timber in use either by reducing its strength or impairing its appearance.
- Defects may be classified as:
  - natural defects,
  - conversion defects,
  - seasoning defects,
  - chemical defects.



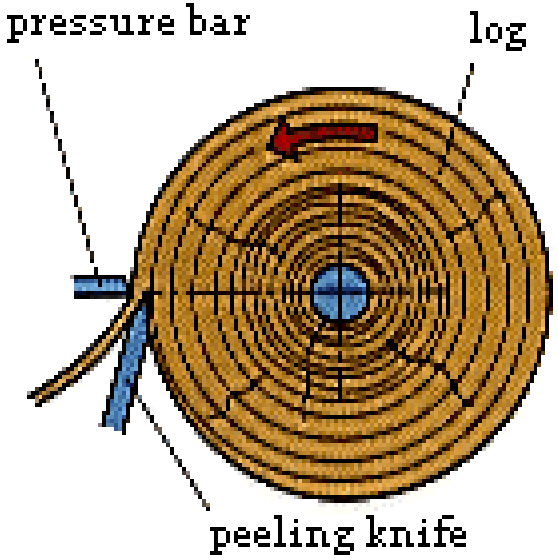
Transforming wood into timber

Slicing

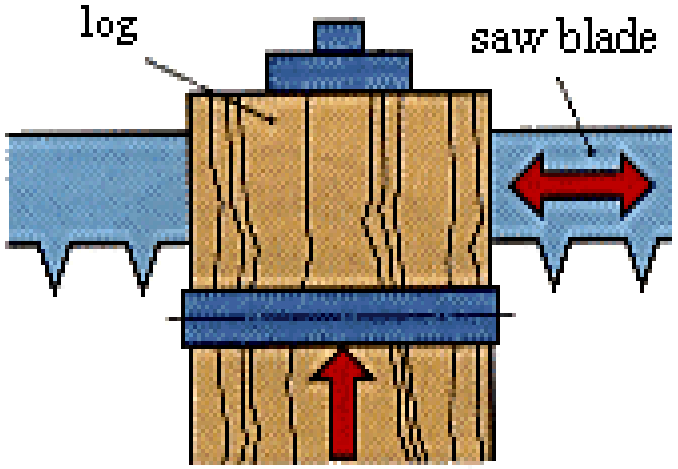




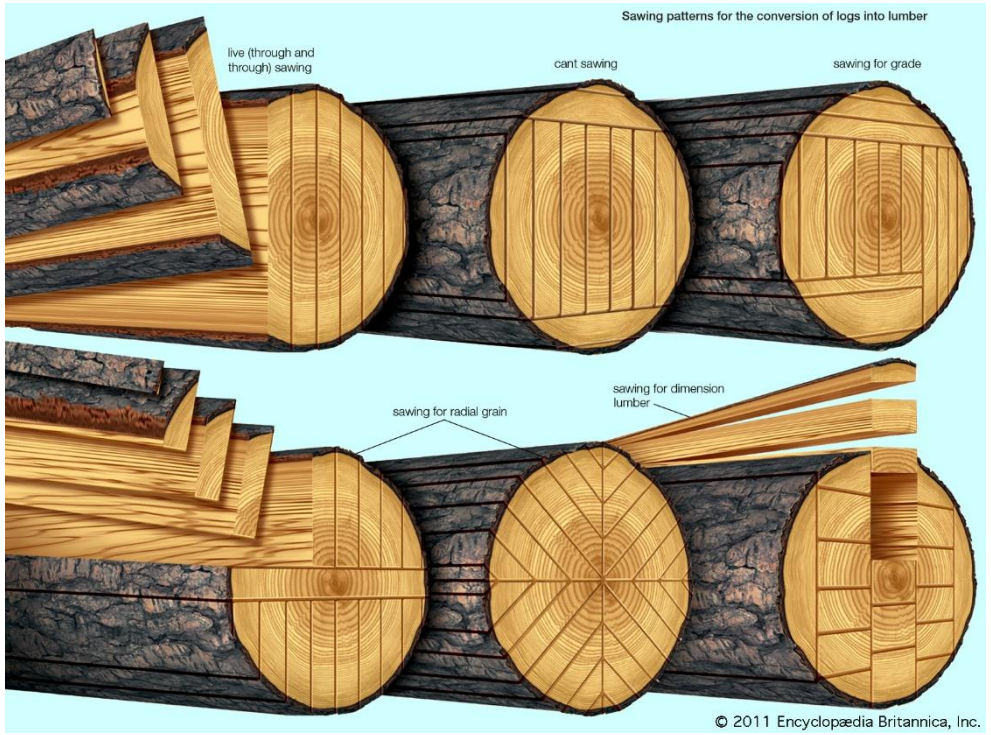
Peeling



Sawing

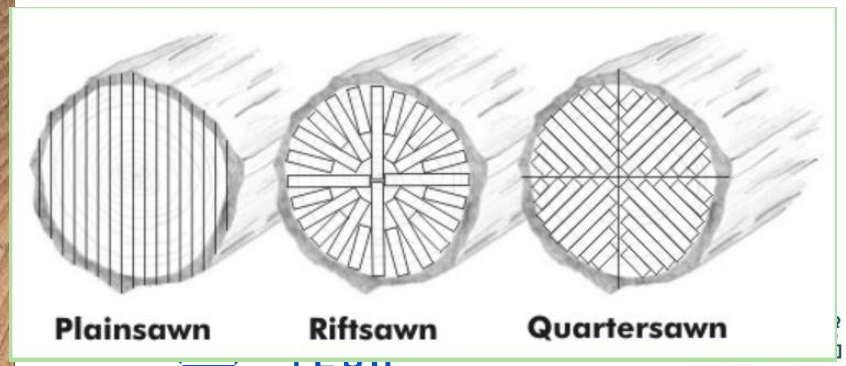


Sawing / Conversion of timber



There are many cutting patterns used to produce timber, but the first step in most sawmill operations will start by scanning the log for the best alignment and cutting pattern for optimum return; then removing one or two wings (slabs) from the logs to give some flat surfaces to work from.

The log, referred to as a *cant*, is turned on a flat face and sawn through and through to give boards (sections) of the required thickness.



By-Product or Main Product

Particleboard

Chips

Shavings

Lumber, also known as timber, is wood that has been processed into beams and planks (differs dimensions)

Solid Sapele Mahogany Hardwood Timber - Kiln Dried - Cut To Size - Planed Square

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More timber materials

Plywood

Cross Laminated Timber (CLT)

Mechanical properties

An understanding of wood and moisture relationships is of great importance to the manufacture and use of wood products, as is an understanding of the mechanical properties of wood.

And, just as shrinking and swelling of wood vary in the radial, tangential, and longitudinal directions, so do various mechanical properties of wood.

So, wood is anisotropic in both its hygroscopic behavior as well as its mechanical behavior.

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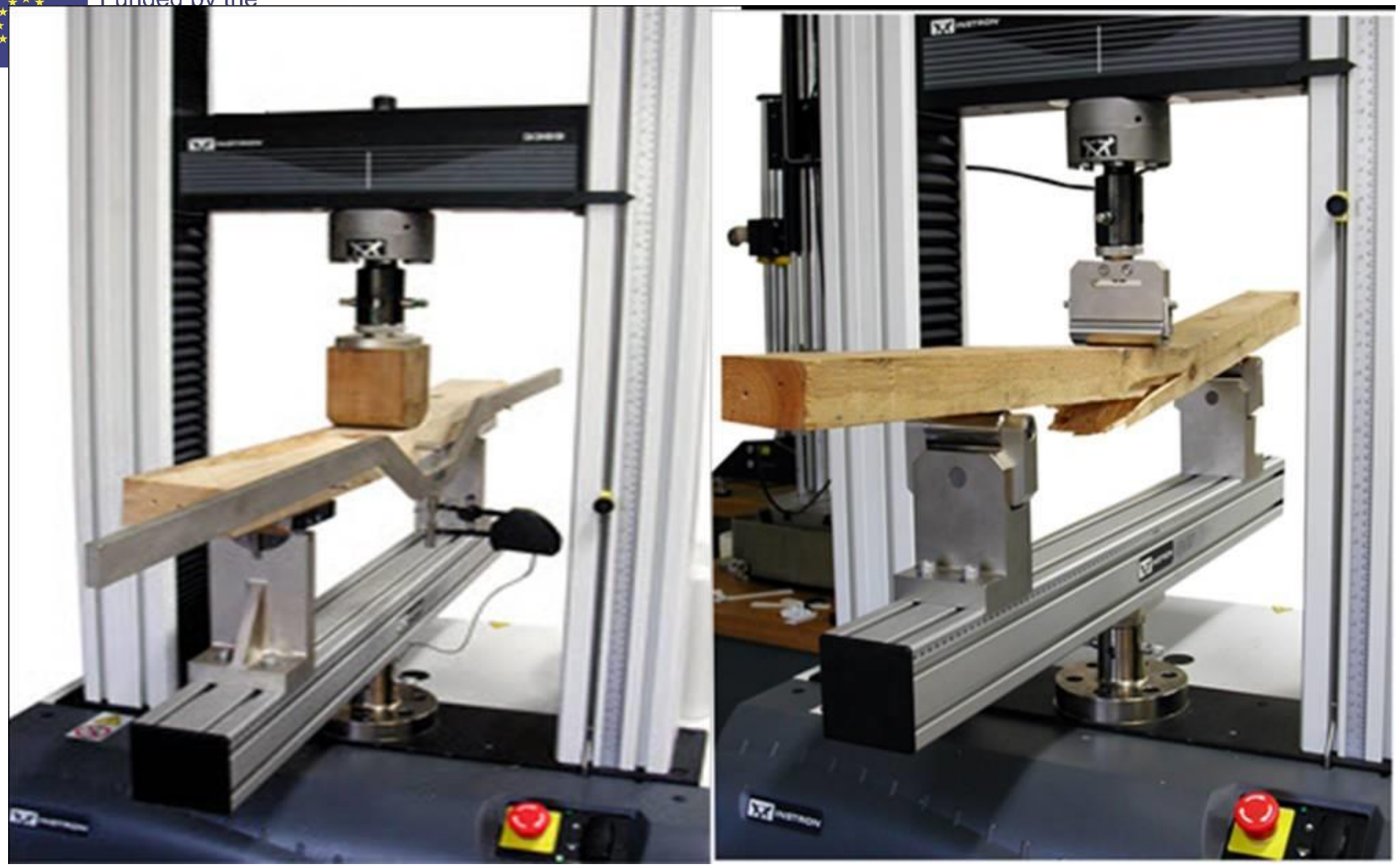


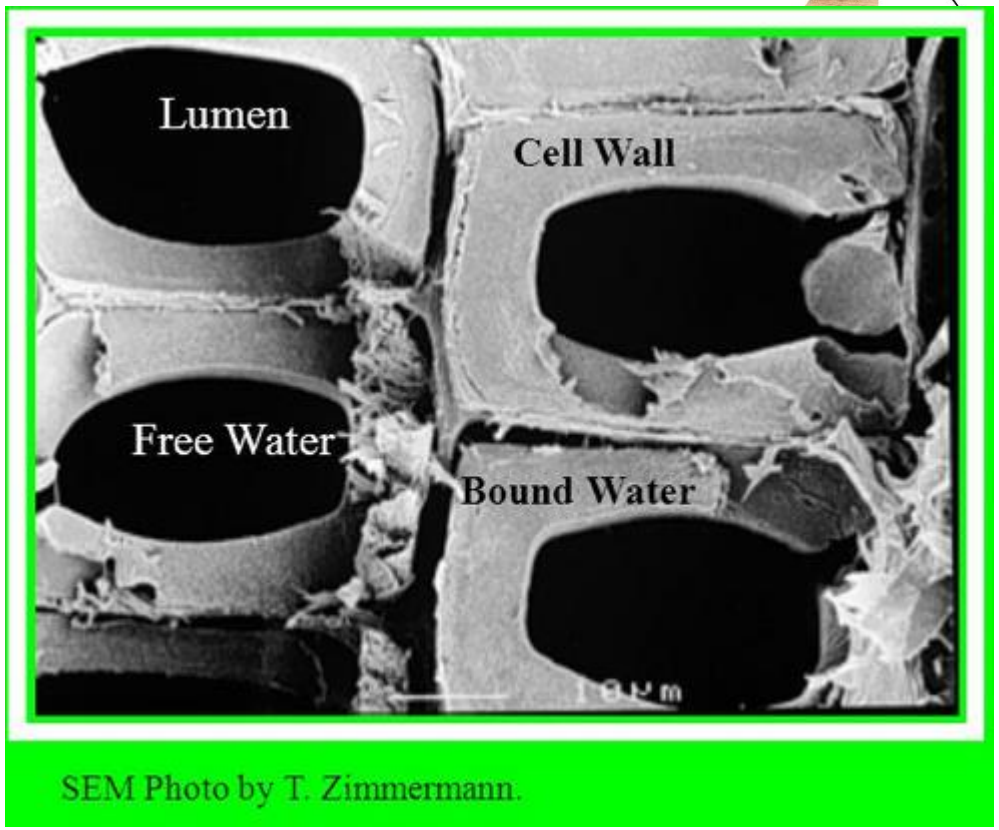
Bending test on a wood lumber

Moisture content

Water is contained in wood as either bound water or free water.

Bound water is held within cell walls by bonding forces between water and cellulose molecules.
Free water is contained in the cell cavities and is not held by these forces –it is comparable to water in a pipe.

> **Fiber saturation point (FSP)-** moisture content when **cells** are completely saturated with **bound water** but **no free water** inside cell cavities.



FSP = 21-32%

- Above FSP - changes affect only on weight
- Below FSP - small changes strongly affect all physical and mechanical properties

The moisture content of timber used for frame structures is typically 15 …24 % (as an average 20 %)

All wood in growing trees contains a considerable amount of water due to the need for water as part of the photosynthesis and growth processes. **This water is commonly called sap**. Although sap contains some materials in solution, it is mainly made of water.

Seasoning (Drying)

- Green wood has 30-200% moisture content
- ~15% when it leaves the mill
- Methods of Seasoning
  - air drying (cheap & slow)
  - kiln drying (fast & expensive)
  - usually a combination
- Uneven shrinkage in different directions during seasoning causes warping, checks, shakes, etc.
- Type of cut controls these problems (vertical is the best)

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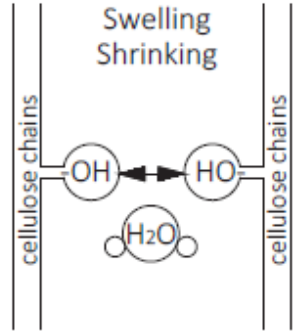
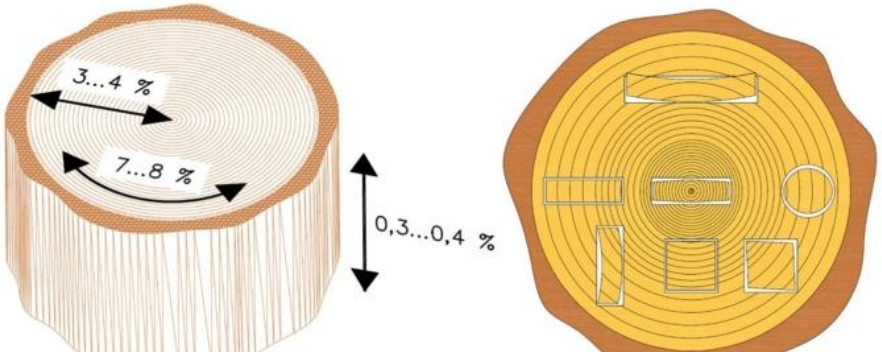
Swelling and shrinking

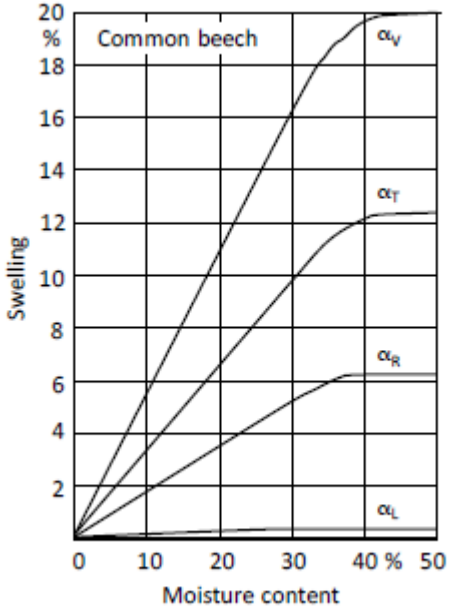


The water molecules stored in the intermicellar and interfibrillar spaces over the hydroxyl groups lead to the cell walls expanding in a process known as **swelling**.
Conversely, the volume contraction that occurs when moisture is released is termed **shrinking**.

There is no further swelling and shrinking above the fibre saturation point, since onl water can be absorbed or discharged from this point.

Wood is an orthotropic material meaning that it shrinks and swells in the direction of the radius, tangent and grain in different ways, which affects the drying result.





Swelling of common beech; α_L longitudinal, α_R radial, α_T tangential, α_V volume.

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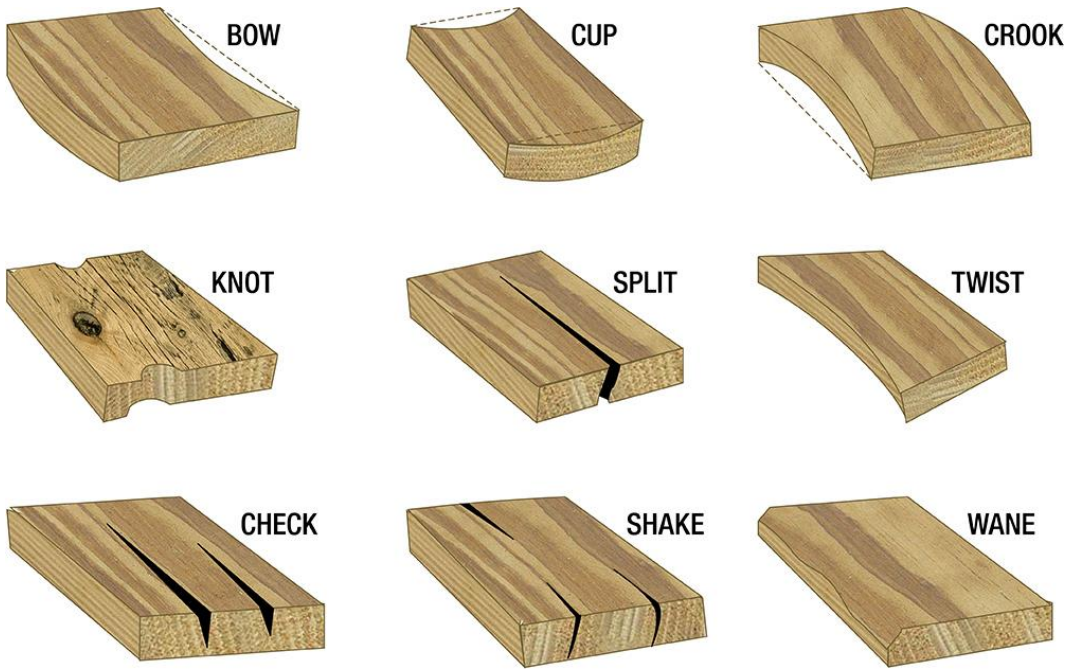
Defects in timber



Diseases of timber

Wet Rot

When subjected to alternate wet and dry conditions, decomposition takes place.
Remedy – well seasoned timber is used with preservatives and paints

Dry Rot

Decomposition of felled timber caused by the action of various fungi.
The fungi reduces the fibre to a fine powder.
Occurs when the timber is not seasoned well and placed in a moist air having no free access of air.
Remedy – when exposed to sunlight or air, the fungi dies.
The best solution is to cut away the affected part and paint the remaining part.

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Organisms that Degrade Wood

Fungi caused dry rot

Spruce Ips Beetle

Bacteria damage black heartwood

Marine-borer damage to a buried pile

Termite damage

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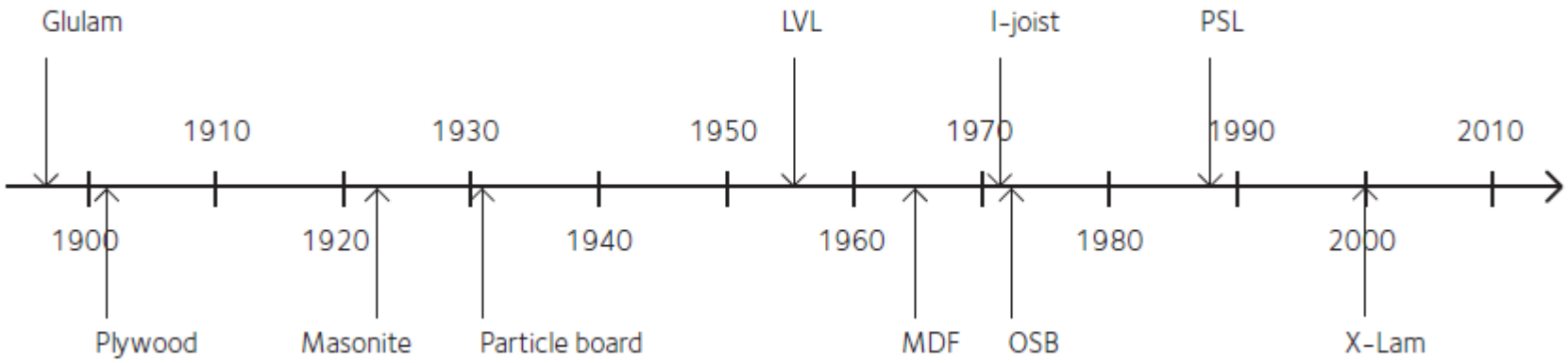
Engineered Wood Products

Normal sawn timber can be found only up to certain dimensions, due to the size of the trees and the industrial process.

For example, the maximum size of sawn timber is a depth of 245 mm and a length of less than 5,5 meters.

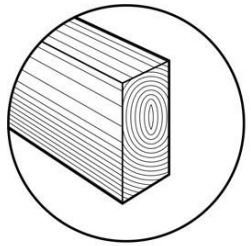
For larger dimensions it is necessary to use some kind of Engineered Wood Product or EWP for short. EWPs are made of wood in the form of sawn timber boards, veneers, particles or fibres held together with, in most cases, some type of adhesive.

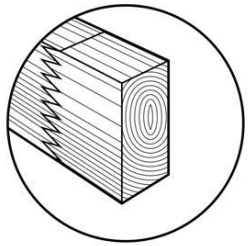
During the 1900's a large number of different EWPs both in the form of beams and in the forms of panels have been invented.

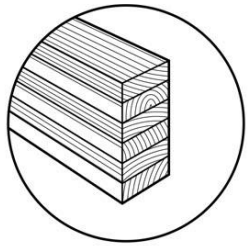


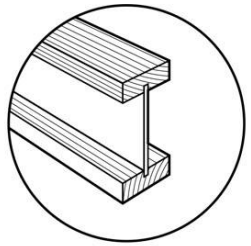
Engineered Wood Products

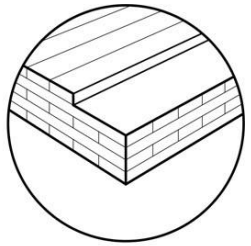
Engineered wood includes a wide variety of products manufactured by bonding together wood strands, veneers, lumber, or other forms of wood fibers to produce large and integral.

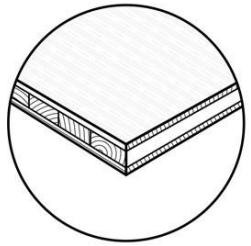

Solid wood

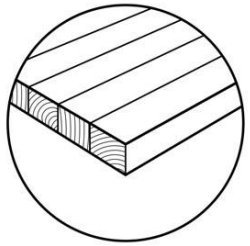

FJ/Solid constr. timber

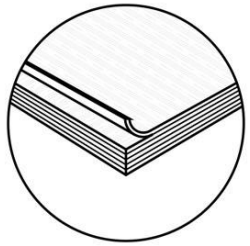

GLT (DLB/TLB)

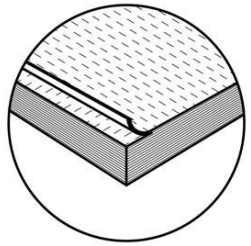

Liteweight timber beams

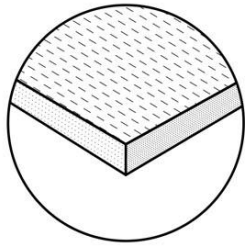

CLT

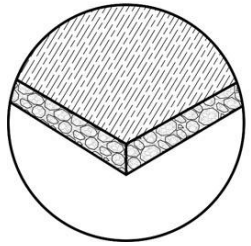

Three-ply laminate sheeting

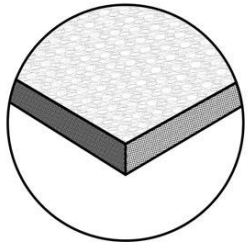

Single-ply sheeting

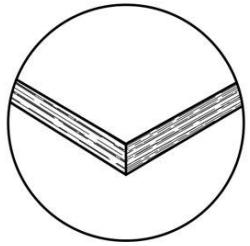

Veneered plywood

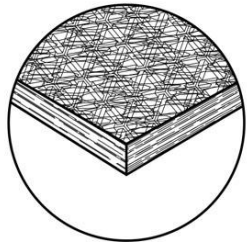

LVL

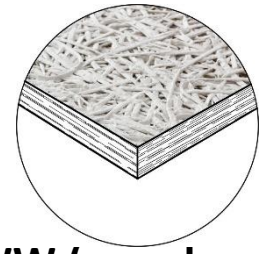

MDF (medium density fiberboard)


Porous wood fiberboard


Cement bonded chipboard


Chipboard


OSB


WW (wood wool)

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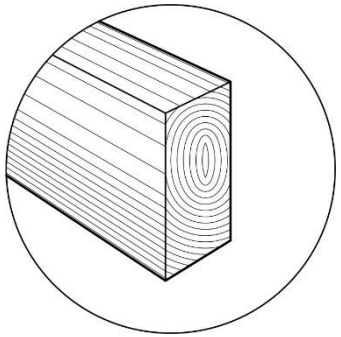

Solid wood
(bar shaped material):

- **Softwood** - ***Spruce, fir, pine, larch***
- ***Load-bearing structures, formwork, cladding, ceilings, walls, roofs, framing***

- **Hardwood** – ***Beech, oak, maple, birch, cedar***

- ***Structural reinforcement for interiors, superior visual qualities***

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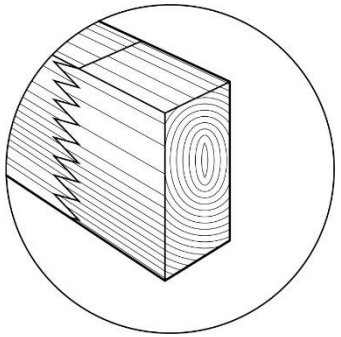

Finger-Joined / Solid construction timber (bar shaped material):

- ***Spruce, fir, pine, larch***

- **Load-bearing cross sections for ceilings, walls, roofs and framing sections**
- **Stacked elements**
- **Semi product for engineered wood**
- **Seasoned (accurate dimensions)**
- **Elements inside the envelope**

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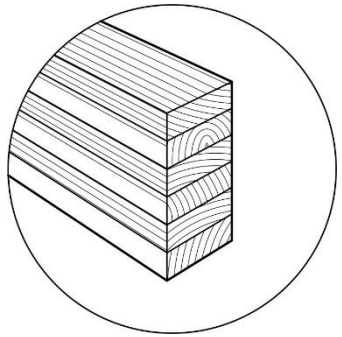

Glulam (bar shaped material):

- ***Spruce, fir, pine, larch, westerm hemlock, cedar,***
- **Universal applications for all bar-shaped structural components, ceiling elements, long-span structural components subject to heavy loads**
- **Straight and curved beams with very stable forms and high visual quality**

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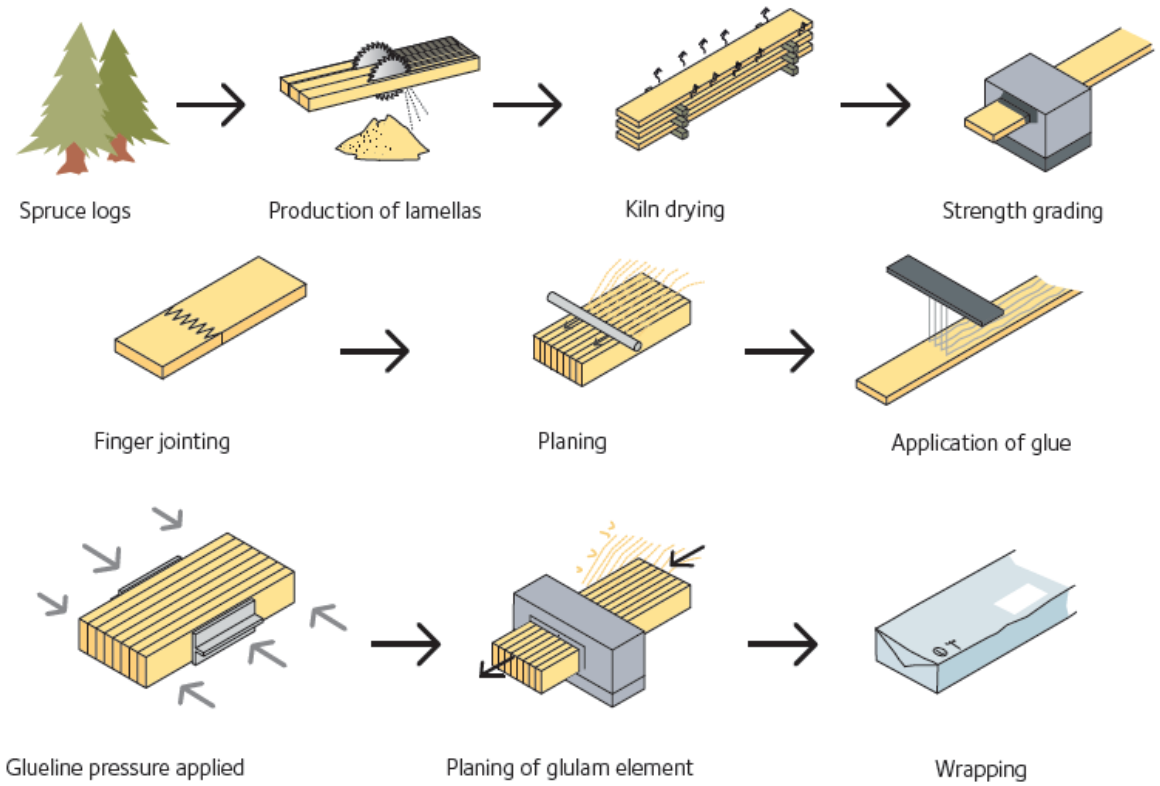
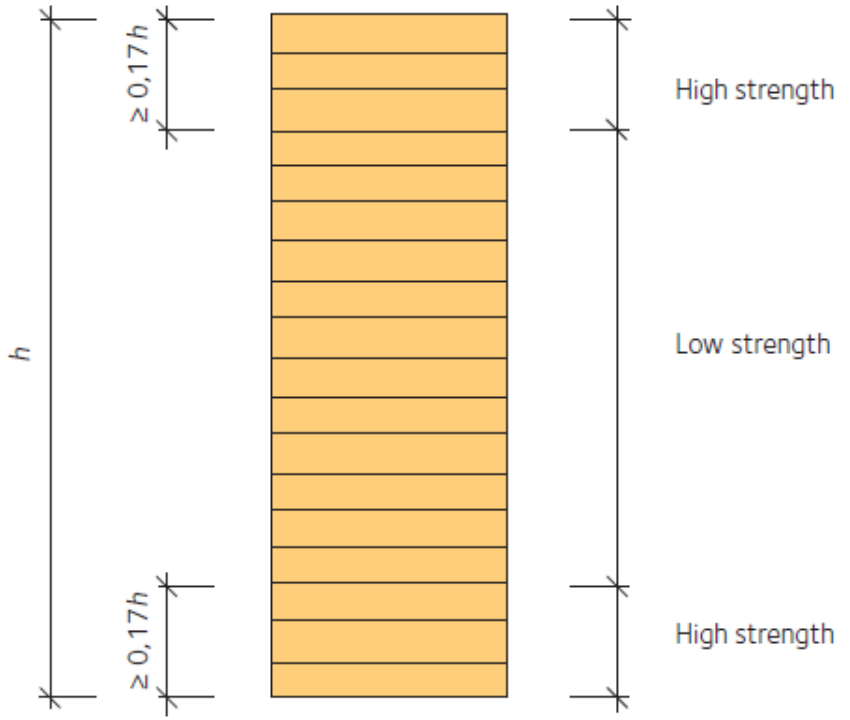
The manufacturing process for glulam beams

Straight glulam is produced in a highly mechanised process.





The lay-up for a combined glulam beam.

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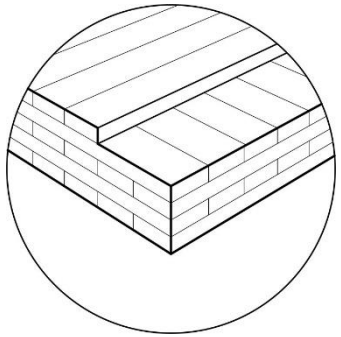

CLT – Cross laminated timber (planks, laminated material)

- *Spruce, fir – rarely pine, larch*
- **Non-load-bearing and load-bearing structural elements, sheeting or panel elements, walls, ceilings and roofs**
- **Non-load-bearing walls**

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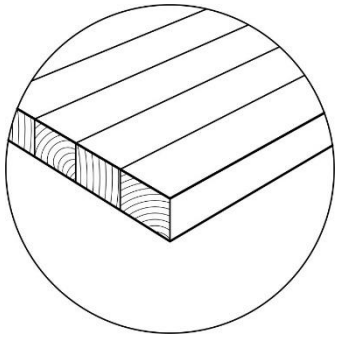
Single-Ply sheeting (planks, Wood based mat.):



- **Softwood - *Spruce, fir, pine,***
- **Furniture and interiors visible surfaces**

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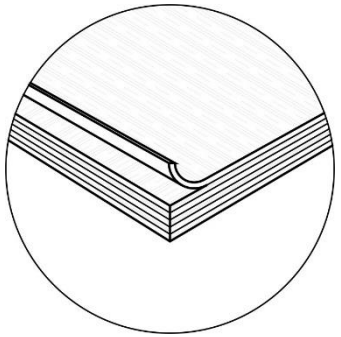
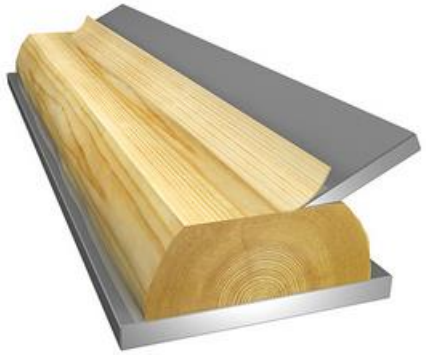


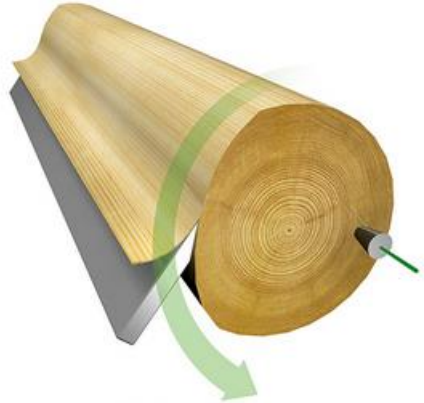
Veneer plywood (Breech Veneer plywood) (veneer, Wood based material):

- ***Spruce, fir, pine, hemlock – Breech is for very strong sheets***

- **Load-bearing ceilings and walls, load-bearing and bracing planking for walls, ceilings and roofs**

- **Weather-proof cladding, formwork, scaffolding, interiors, furniture**





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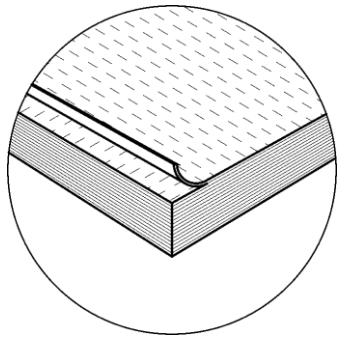
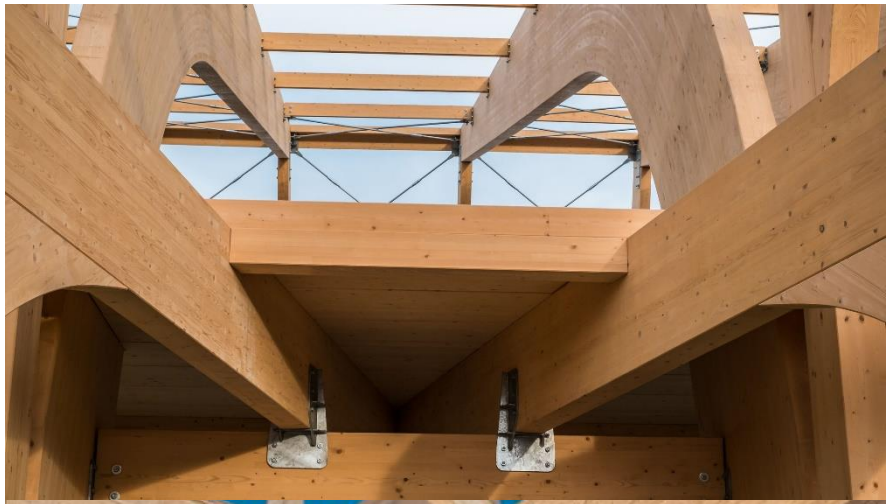


LVL – Laminated Veneer Lumber (veneere, Wood based material):

- *Spruce, beech, fir, pine,*

- **Load-bearing structures, beams, supports, flanges and struts of truss beams and spatial trusses, support structures for large halls**

- **Interiors and furniture**



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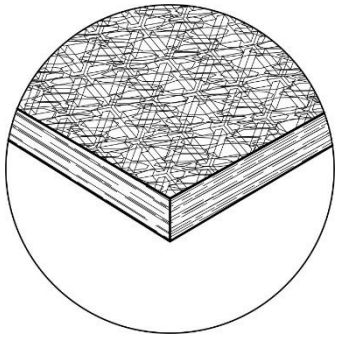

PSL (Parallel strand lumber)(strands, Wood Based material):

- *Poplar, fir, pine*

- **Applications with extreme structural requirements e.g. bottom plates, edging boards or lintel areas, wall, roof and ceiling plates, supports and beams**

- **Ceiling and floring panels**

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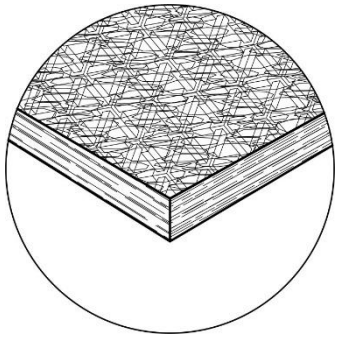

OSB (Oriented strand board)(strands, Wood Based material):

- *Poplar, fir, pine, alder,*

- **Load-bearing walls, load-bearing and bracing planking for floors, walls, ceilings, box elements and roofs (outside with weather protection), webs of I-beams**

- **Mounting panels for flooring, concrete formwork, interiors, furniture**

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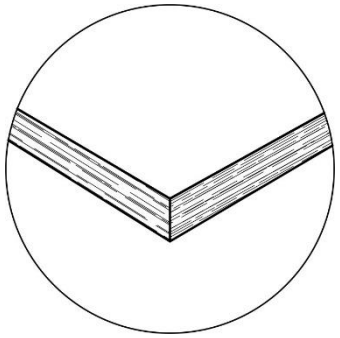

Chipboard (strands, Wood Based material):

- *Pine, spruce, beech, birch, alder, ash, oak, poplar, chestnut,*

- **Can be universally used for non-load-bearing, loadbearing and bracing planking and as filling panels in timber frame construction**

- **Interiors, furniture**

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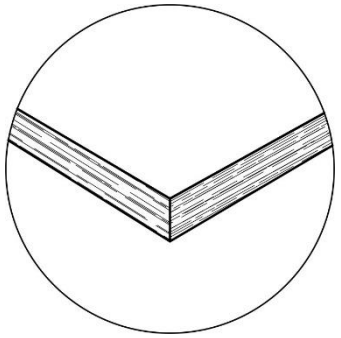

Cement bonded Chipboard (strands, Wood Based material):

- *Spruce, fir, softwood, chips bonded in cement,*
- **Fire-resistant panels, load-bearing and bracing planking for interiors and exteriors, facade cladding**
- **Non-loadbearing interior walls, sound and thermal insulation**

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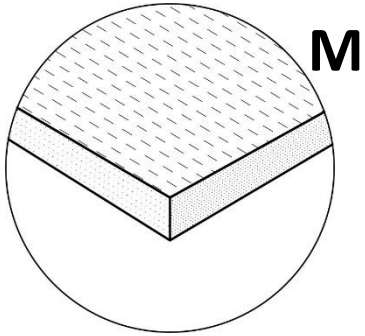
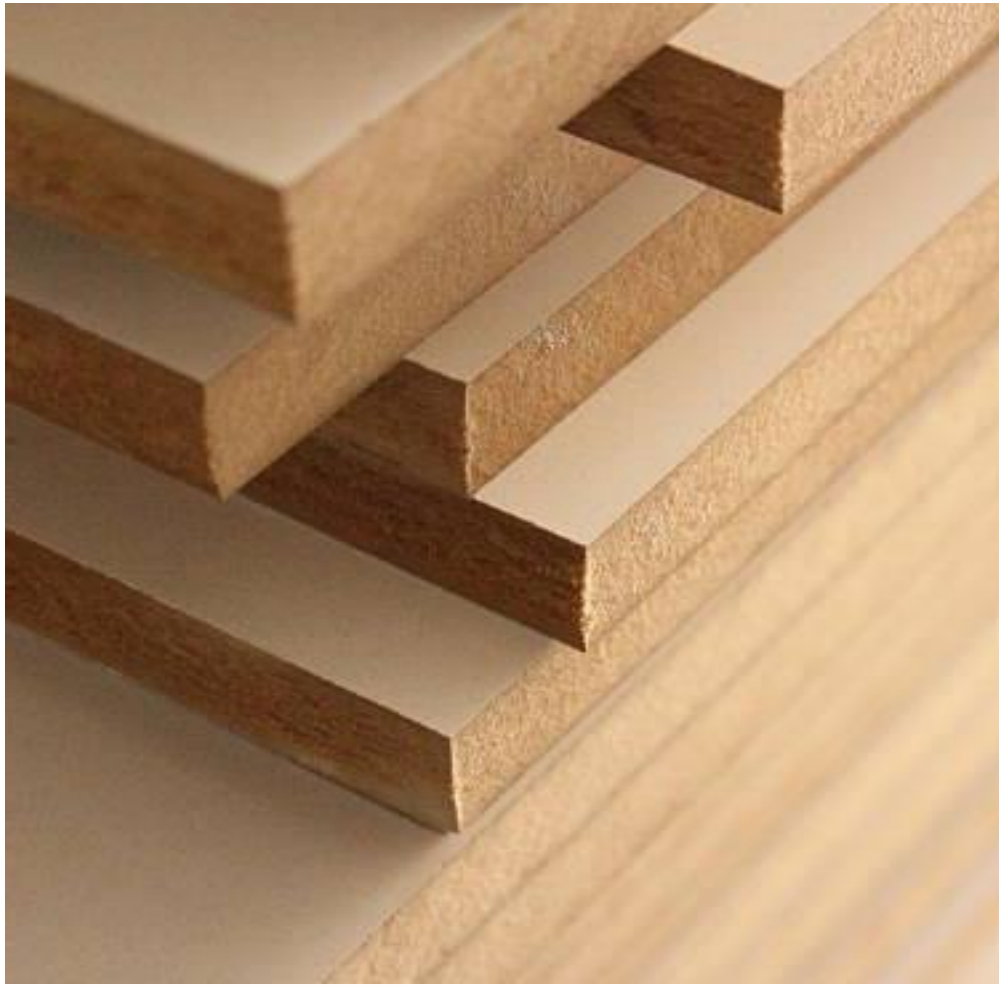


MDF – medium density fibreboard (fibre, Fibre Based material):

- *Spruce, pine, fir, beech, birch, poplar, eucalyptus,*

- **Interiors, acoustic elements, furniture**

- **Limited use as load-bearing and bracing planking and to make wall, ceiling and roof panels**



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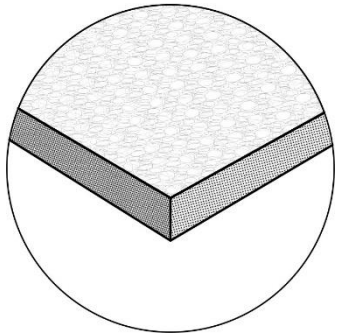

Porous wood fibreboard (fibre, Fibre Based material):

- *Spruce, fir, pine, beech,*
- *birch, poplar, eucalyptus*

- **Insulation inside and out and between frames and rafters of walls and roofs, insulation of partition walls, footfall sound insulation**

- **Underlay boards for roofs or to make the building envelope more windproof**

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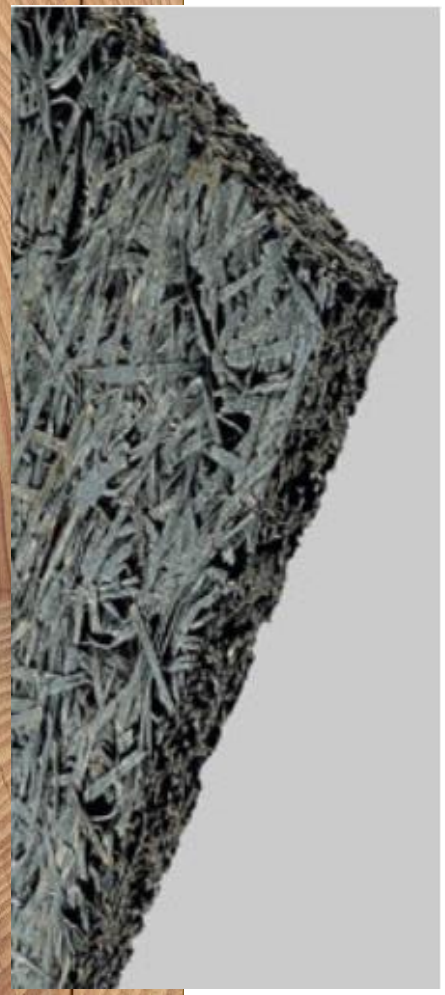

Lightweight wood wool board(wood wool, Fibre Based material):

- *Spruce, pine,*

- **Plaster base for ceilings and soffits, acoustic panels for soundproofing**

- **Interior and exterior planking, thermal insulation in summer**

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Products:

BAR SHAPED

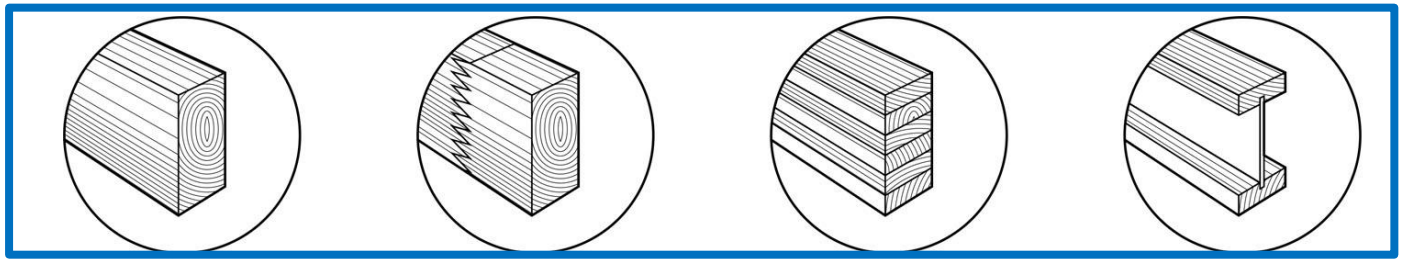
PLANKS

VENEERE

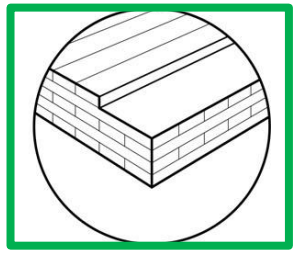
FIBRES

CHIPS

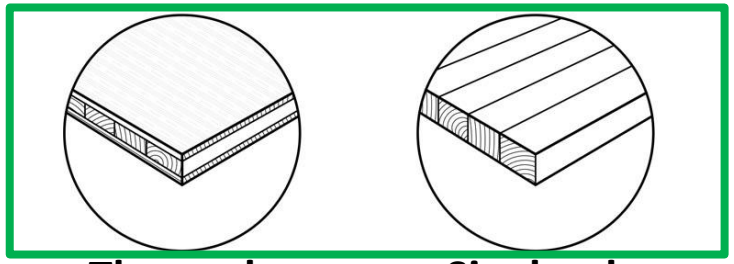
WOOL



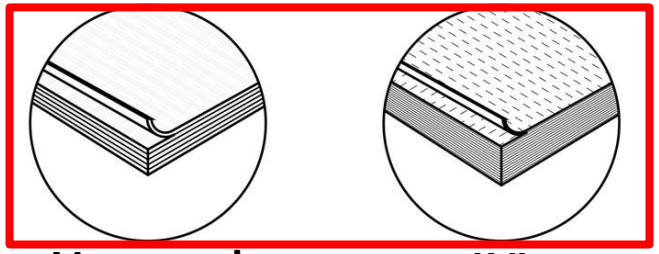
Solid wood | FJ/Solid constr. timber | GLT (DLB/TLB) | Liteweight timber beams



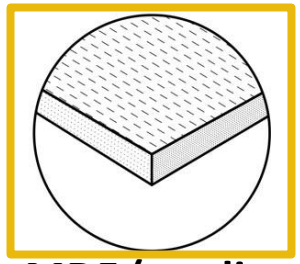
CLT



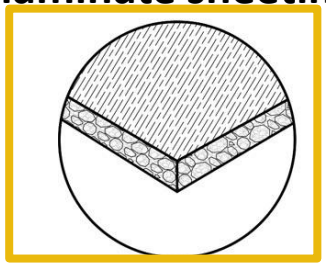
Three-ply laminate sheeting | Single-ply sheeting



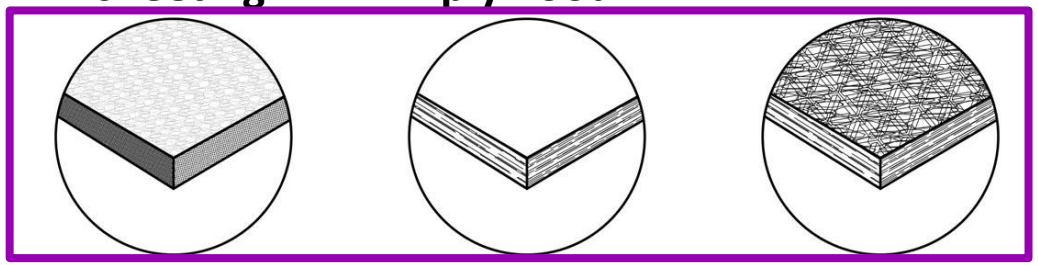
Veneered plywood | LVL



MDF (medium density fiberboard)



Porous wood fiberboard



Cement bonded chipboard | Chipboard | OSB

WW (wood wool)

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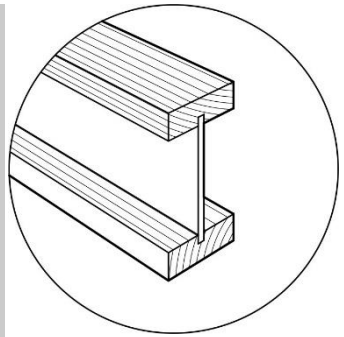

Lightweight timber beams (mixed products):

- I-joists are structurally engineered timber joists comprising flanges made from solid timber or LVL and a web made from OSB, plywood or particleboard.
- The flanges and web are bonded together to form an I-section member, a structurally efficient alterative to conventional solid timber.

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Thank you!
Questions?

Material for this presentation is prepared with Christina Tirteu material

Are the bomboo materials a wooden material?