Wood based construction – raw materials

There are two kinds of raw materials in wood based constructions:

1. Structural materials
2. Non-load-bearing materials

1. Structural materials

- Natural (solid) wood
- Glued materials
- Wood based materials (beams and panels)
- Metals
- Plastics

1a. Solid wood

Available as:

- Non-debarked roundwood – rarely used.
- Debarked roundwood – used occasionally (e.g. in large trusses, bridges, etc.)
- Hewn timber – not used today
- Sawn timber – used mostly.

Important properties

- Wood species
- Mechanical properties (strength, elasticity)
- Density
- Moisture content
- Shrinkage and swelling
- Thermal expansion
- Durability
- Fire safety
- Thermal properties and physiology
- Environmental considerations

Wood species:

Wood species suitable for construction:

- In theory: all species
- Practically: species above 400 kg/m^3 density

Wood species considered suitable:

- Softwoods: Silver fir, Douglas fir, Scots pine/Austrian pine
  Larch for special purposes
- Hardwoods: Oak, Black locust
  Beech, Poplar, Alder – occasionally for less demanding applications.

Hardwoods are rarely used. Some experience in Hungary and Germany, esp. in historic structures.

Mechanical properties.

Wood as a load-bearing element – stress design is crucial!

Traditionally: based on prior experience.

Recently: using stress design!

Stress design requires design values (strength, MOE.) - governed by EN 518:

- Two species groups: hardwoods (D) and softwoods (C) (includes poplar)
- Several strength classes in both groups
- EN 1912 identifies the strength class for each material classified according to national standards.
- Materials may also be classified using non-destructive testing, according to EN 338 using density and MOE as criteria (same groups as EN 518).

Another possibility: online strength grading – governed by EN 519:

- Machine stress rating (based on actual bending between rollers)
- Vibration based methods – rarely used
- Density measurements – density mapping
- Optical scanning
- May provide strength class, or actual design values.

Density

Significance:

1) Related to strength. Not a very close relationship! (MOE is usually a much better predictor)
2) Related to weight – the structure has to support its own weight!

Depends on wood species, site and climate!

General rule: ρ < 400 kg/m^3 is not feasible.

Good to know: wood has excellent *specific strength*!

Moisture content

Has an effect on:

- weight
- mechanical properties (below FSP)
- shrinkage and swelling
- deformation

Important: MC should be about 1-2 % below the expected EMC of the structure!

EMC values in different circumstances:

- in an enclosed and heated space: 9 ±3%
- in an enclosed, non-heated space: 12 ±3%
- outside, under cover: 15 ±3%
- outside: above 18 %
- in soil or water contact: above FSP.

Shrinkage, swelling deformation

Related to MC (between 0 and 30 % MC).

Shrinkage and swelling: minimal along the grain, significant across the grain! Important when manufacturing glued products (e.g. ring orientation when producing panels).

Deformation: shrinkage is different from tree to tree, and depends on the location within the bole. This causes deformations. Problematic in beams, poles, trusses, etc.

Solution: using materials of appropriate moisture content! No MC change = no deformation.

Another solution: using laminated products! (deformations get restricted and/or equalized).

Thermal expansion

Not very significant in wood – counteracted by shrinkage.

Durability

Wood should last until the end of the structure's lifetime (usually 50 years.)
Very much affected by the climatic conditions:

- Very durable under 15 % EMC. Some wood-boring insects (e.g. longhorn beetle) may still cause damage.
  Initial wetting: some fungi retain water and maintain the necessary MC!
- Above 15%: fungal and insect damage. Typical in outside climates.
- In ground or soil contact: plenty of water and oxygen for fungi and insects!
- Very high MC (e.g. in soil or underwater) – not enough oxygen for fungi and insects. Slow damage by bacteria, or marine borers (in seawater).

Durability is effected by:

- Wood species: some species are naturally very durable. E.g. oak and black locust heartwood, or larch.
- Design: structural wood protection! (E.g. protection from direct sunlight and rain, good drainage, etc.)
- Chemical protection: effective but with some technical problems and environmental concerns!

Fire safety

Wood above 6 mm thickness is flammable, normal combustibility (B2).

Wood is flammable, but it may not behave worse than other materials in a fire!

Cause: wood is a good thermal insulator – charring on the outside, slow propagation towards the inside!

Design for fire is possible in some countries! Propagation speed:

- Norway spruce: 0.6 – 0.7 mm/min
- poplar: 0.8 mm/min
- oak, black locust: 0.3 mm/min

Design considerations:

- Large cross sections are better (use less beams with large cross sections)
- Should be large in both directions!
- Corners burn easier – avoid complex cross sections and ribbed surfaces!

Thermal properties and physiology

Wood:

- good thermal insulation
- low weight – ineffective for heat storage
- acoustic properties
- humidity control!

Solid wood buildings – worse in terms of thermal insulation, but better for heat storage and excellent humidity control.

Woodframe buildings – excellent thermal insulation, but low heat storage capacity and no humidity control.

Environmental considerations

Wood:

- renewable raw material
- low energy consumption
- carbon sequestration
- reuse and recyclability.

Tackle climate change – use wood!

1b. Glued construction wood

Advantages:

- Added value (valuable products from lower grade raw materials
- Larger sizes
- Dimensional and form stability
- Better control of physical and mechanical parameters (engineered properties.)

Glued products:

- end-jointed lumber (KVH)
- solid wood panels
- glued-laminated beams
- 2 and 3 layer laminates, Kreuzbalken

Will be discussed in detail during the semester.

1c. Wood based construction materials

Two-dimensional (composite panels): chipboard, fibreboard, plywood, OSB, MFP, gypsum-bonded fibreboard, cement-bonded chipboard, etc.

One-dimensional (SCL, structural composite lumber): LVL, PSL, LSL, Scrimber

Composite panels:

Fibreboard

- Hardboard, medium density and insulation boards.
- Low strength – rarely used in wood construction.
- Low density fibreboard is used as insulation
- Special "breathing" boards used in walls, ceilings and roofs.

Chipboard

- High density, low strength.
- Not ideal for wood construction, but used as sheathing.

Plywood

- High strength with relatively low density
- Strength depends on species. As strong as the raw material in the longitudinal direction
- Used as sheathing, I-beam webs, and, occasionally, as connectors.
- Grades:
  - EN 636-1/EN 314-1 – Plywood for interior applications
  - EN 636-2/EN 314-2 – Plywood for humid environment
  - EN 636-3/EN 314-3 – Plywood for exterior applications

OSB (Oriented Strand Board)

- Made of strands (large, thin, long, slender chips specially made for this purpose.)
- Outside layers oriented longitudinally, inside layers transversely.
- Strength similar to plywood.
- Higher thickness swelling – screws may sink too far (connection strength decreases.)
- Uses: same as plywood.
- Grades (EN 300):
  - OSB 1 – non-structural applications
  - OSB 2 – structural – non-moisture resistant
  - OSB 3 – structural – moisture-resistant
  - OSB 4 – structural – high-performance, highly moisture-resistant (for I-beam webs)

MFP (MultiFunktionsPlatte)

- Special, high-performance chipboard-type product
- Uses: same as plywood.

Gypsum-bonded fibreboard

Inorganic-bonded panel with relatively low density and high strength
May be used as sheathing and cross-bracing.
Acceptable as fire-barrier

Cement-bonded particleboard
High density and low strength – doesn't work as cross-bracing.
Effective fire-barrier.

Structural composite lumber:

LVL (Laminated Veneer Lumber)

- Micro-Lam (US), KERTO (Europe)
- Similar to plywood, but layers are oriented in the same direction
- Usually made of Norway Spruce with a phenolic resin.
- Thickness: 27-90 mm, Width: up to 2.5 m, Length: up to 14 m
- Types:
  KERTO-S – traditional LVL (min. strength of 44 MPa!)
  KERTO-Q – contains crossbands (for surfaces.)
  KERTO-T – using lighter veneers, used as studs in lightframe construction.

PSL (Parallam)

- Made of veneer strips in a microwave frame press
- Large cross-sections (up to 28 x 42 cm)
- Relatively high density and strength (approx. 40% densification)
- Advantage: non-laminated structure, less prone to delamination
- Not common in Europe.

Scrimber

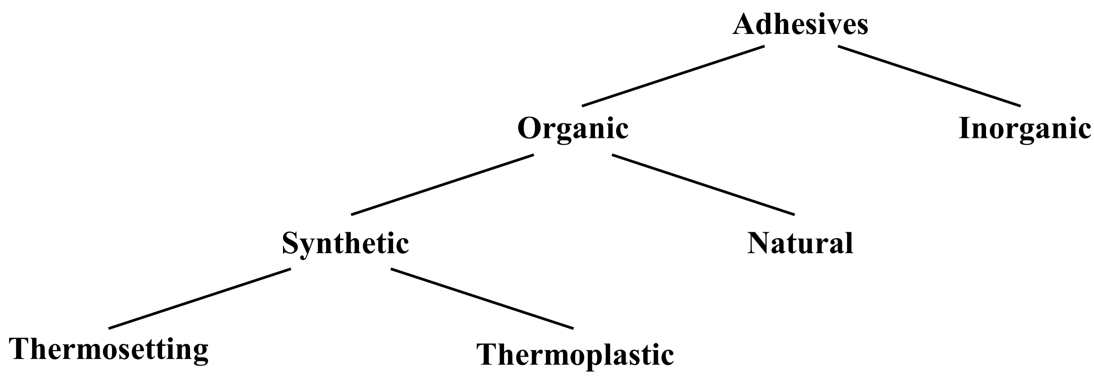
Similar to parallam, but made of crushed wood strips instead of veneer. Not present in Europe.

LSL (Timberstrand)

- Similar to OSB, but strands are oriented in the same direction, and longer.
- Made with isocyanate resin – very strong.
- Thickness: --- Width: --- Length: ---
- Not common in Europe.

2. Other raw materials

2a. Adhesives



Thermoplastic resins

- PVC, PVAc, etc.
- Easy to work with
- Strong and very elastic bonding
- Problem: creep! Not suitable for structural applications. ☹
- Preferred for joinery applications

Thermosetting resins

Strong resins, most of which are suitable for structural applications.
Resin types:

Urea-formaldehyde (UF)

- The “original” synthetic resin
- Cheap
- Strong bonding, cold-water resistant
- Poor gap-filling properties
- Light-coloured
- Starts deteriorating above 60°C
  (Structural bonding reqiures a heat-resistance of up to 80°C!)
- Environmental problem: formaldehyde emmission!

Phenol-formaldehyde (PP)

- Strong bonding, highly water-resistant
- Short pot life
- Excellent structural adhesive

Melamine-formaldehyde (MF)

- Strong bonding, highly water-resistant
- Can be modified to be cold-setting
- Often used as a modifier for UF
- Good gap-filling
- Light-coloured
- Suitable for HF gluing.
- Very expensive…

Resorcinol-formaldehyde (RF)

- Very strong and durable
- Can be cold-setting using an acid catalyser
- High strength, highly water-resistant
- Safe to use in any structural application, and in association with othe resins.

Note: formaldehyde resins are often used in mixtures (e.g. melamin-urea-formaldehyde, or phenol-resorcinol-formaldehyde) to improve the properties of cheaper resins / to make high-performance resins cheaper…

Epoxi resins

- Two component resins
- Can be used as thermosetting or cold-setting
- High strength, good moisture and heat resistance
- Not very elastic, prone to shrikage
- Good gap-filling, does not require clamping (good for on-site repairs.)

Polyurethane resins (PUR)

- High strength, highly moisture resistant
- One- or two component glues (one component: moisture-cure adhesives)
- High strength bond, but less moisture resistant than RF
- Bonds to a wide range of materials
- Light-coloured gluelines; does not show up after surface treatment.