Puu-28.5000

Introduction to Wood Properties and Wood Products

Wood products and their applications

11th November 2015
Wood products

• What wood products are there?
• Why do we have these?
• What are their characteristics?
• Where might they be found- in what application?
Production of wood products

(Source: UNECE Timber Committee Forest Products Statistics)
The pros and cons of wood!
Properties of wood

- **Specific stiffness** parallel to the grain comparable with mild steel
- **Specific tensile strength** (parallel to the grain) 4 x greater than mild steel
- The stiffness of **microfibrils** (the basic building blocks of wood) comparable to aramide (e.g. Kevlar™) fibre
- On a specific basis the microfibril is 3 x stiffer than glass fibre (used extensively in fibreglass composite products)
Other properties of wood

- Low thermal conductivity (good insulator)
- Aesthetically pleasing (looks good!)
- Plentiful – wood literally does “grow on trees”!

- Renewable (CO₂ and sunlight)
- Biodegradable
- Low energy of conversion (low “embodied energy”)
- Carbon “sink” potential (more about this in a minute)

- But...... there is increasing competition for this resource
- Should lead us to be more efficient in the use of the raw material in the future....
So what is the downside?

• The properties of wood are directionally dependent
• There is large variability in wood properties due to its structure and to “defects”
• Swells and shrinks: dimensionally unstable
• Subject to biological decay: it rots
• It burns!
• Only available in a limited range of shapes and sizes!!
• For this reason (and others), in addition to sawn wood there are a great many wood-based composites, modified wood products and, increasingly, wood-fibre reinforced composites
The family of wood products
Wood products

• **Sawnwood:**
  - “Engineered wood” products
  - Wood-based panels

Wood-based composites:

- Glue laminated timber (glulam)
- Laminated veneer lumber (LVL – Kerto)
- Plywood
- Oriented strand board (OSB)
- Particleboard (chipboard)
- Medium density fibreboard (MDF)
- Softboard/hardboard

- Fibre reinforced composites
- Modified wood
Sawnwood

(Source: Society of Wood Science & Technology)
Wood-based composites

- Wood can be de-constructed and then re-constructed in the form of a **composite**, so that many of less desirable features can be "engineered out", or new properties introduced, leading to, e.g.:
  - Better performance
  - More homogeneous products
  - Reduced variability
  - Larger range of sizes
  - Reduced swelling and shrinkage
  - Improved fire and decay resistance
- This then makes wood more attractive as a material
What else?

• Composites make effective use of raw materials that might otherwise be regarded as “waste” (e.g. wood chips & sawdust)

• Composites can also make effective use of recycled or reclaimed materials (many existing manufacturers use up to 90% recycled wood in particleboard for example)

• Relatively small amounts of fossil-based adhesives (usually 8-10% by dry weight) are used in the manufacture and even these could be replaced by renewable resource-based alternatives (or even eliminated!)
## Composites based on wood

**Wood can be reduced in size to:**

- Sawn timber, lamellae
- Veneers
- Strands, strips, particles
- Wood fibres
- Cellulose

**Composite material:**

- Glue laminated timber
- Plywood, LVL
- OSB, particleboard
- Paper, MDF, Wood-polymer composites (WPCs)
- Cellulosic “Nanocomposites”
Wood-based composites

• Typically wood-based composites are formed from wood elements that are mixed with an adhesive (glue) and are formed into a panel or beam
• Sounds simple……………!
Basic steps

- Raw material prepared (logs, recycled wood)
- Converted into particles (fibres, chips, strands) or veneers—"size reduction" step
- Particles/veneers dried
- Particles/veneers classified/graded
- Blended with a resin and additives
- Particle/resin/additive blend ("furnish") is formed into a mattress or "layed-up", in the case of veneers
- Hot pressed to compact the particles/veneers together and cure the resin
- Cooled and finished
- Further processing
Interactions during manufacture!

(Source: Maloney, 1993)
What is a wood-based composite?

- A material composed of wood **particles**, ranging in size from fibres to lamellae (including particles, strands and veneers), bonded together with an adhesive.
- Typically panel products
- Properties range from “non/semi-structural” to “structural”
- Typically used in the construction and furniture industries
- Products manufactured in many regions Worldwide
- Around 40 million cubic metres produced in European Union annually
What is a wood-based composite?

- Broadly defined as either structural or non-structural
- Structural wood-based composites include products such as:
  - Glue laminated lumber (glulam)
  - Laminated veneer lumber (LVL)
  - Plywood
  - Oriented Strand Board (OSB)
  - And others.....
- Whereas non-structural wood-based composites include:
  - Particleboard ("chipboard")
  - Medium density fibreboard (MDF)
  - Soft-board & hardboard
  - These are often referred to as “panel” products
Why wood-based composites?
Drivers: technical

- Wood available only in limited shapes and sizes – panel products and composites can be made to a range of dimensions
- Create new properties in the material. Wood is highly anisotropic, wood-based composites can be “engineered” to have tailored properties
- Improve dimensional stability (e.g. plywood)
- Improve machining properties (e.g. MDF)
- Reduce variability in properties by removing or randomising defects
- Visual improvement through lamination; a greater range of finishes possible
- Good strength/stiffness to weight ratios – good in applications and reduces transportation costs
Drivers: commercial

• Utilise small dimension wood and poor quality material
• Effective use of “waste” resources (sawdust, shavings, the “urban forest”)
• Use non-wood lignocellulosic resources
• Value added opportunities
General issues

• Raw material; trends towards poorer quality, fast grown species
• Competition for the forest resource from energy and other uses (e.g. recreation)
• Good way of utilising recycled or reclaimed wood
• Non-wood raw materials being used (cereal straws)
  – Wheat straw, kenaf etc
• Formaldehyde from the binder (adhesive): a big issue
• Volatile Organic Compounds (VOCs) in general
Wood Based Panel Consumption 2004

Wood-based panels (non-structural)
Particleboard: characteristics

- Largest production volume worldwide
- Manufactured from particles of wood (or non-wood resources) that have been “chipped” from larger pieces of wood
- Chips typically have dimensions of several millimetres or 10s of millimetres. Core material of coarser material (larger chips)
- Usually bonded with Urea Formaldehyde (UF) resins, or resins “fortified” with melamine to make them more moisture resistant (MUF)
- Mainly used for furniture, worktops, DIY (Do-it-yourself), flooring, roofing and general construction
- Particleboard density typically in the region of 650-750 kg/m³
Particleboard (chipboard)

• Particleboard arose due to scarcity of veneer and the desire to utilise waste materials such as sawdust and planer shavings etc.
• It was first produced in Germany in the 1940s
• Rapid growth followed
• Switch to virgin wood for the manufacture of chips so as to give better performance
• Switch back to recovered & waste wood with the desire to reduce waste and improve resource efficiency. Now, a significant amount of raw material is waste, or recovered wood.
• Probably no coincidence that production of PB and other wood-based composites arose at the time when waterproof glues such as urea formaldehyde and phenol formaldehyde became widely available
Environmental credentials

- “Kronospan chipboard comprises 70% recycled fibre and 30% virgin FSC traceable timber – diverting 300,000 tonnes of waste from landfill per year. The product has also been given a carbon-positive award by The Blue Green Carbon Company. Our chipboard exceeds all the relevant UK and European standards; we manufacture via a quality system accredited to BS EN ISO 9002:2000; all Kronospan chipboard is independently certified as low formaldehyde, meeting the European E1 standard”

Kronospan corporate literature (http://www.kronospan.co.uk/)
Chipboard

Source: European panel federation
Structure of particleboard

- Particles of mm dimensions
- Typically 3 layers – surface or face material of fine particles
- Density profile developed during manufacture for improved properties in bending and a harder surface
Applications for particleboard

• Applications:
  – Examples include: general building work, joinery, upholstered furniture, furniture carcass, veneering, foiling.
• Application [brochure](#)
Medium Density Fibreboard – MDF (LDF and HDF)

- MDF, LDF (Low Density Fibreboard) and HDF (High Density Fibreboard) are dry-formed fibre boards (as distinct from hardboard)
- It is a relatively “new” product, with significant growth since the 1980’s
- Manufactured from wood fibres that have been produced in a pressurised refining process
- Wood fibres are typically 1-3 mm long and 20 µm in diameter
- Usually bonded with urea formaldehyde (UF) or MDI (methylene diphenyl diisocyanate) resins
- Produces a very “fine-scale” and homogeneous product, suitable for a variety of applications
- Can be worked, turned and laminated – used for furniture, fittings, partitions, wall-linings, mouldings, flooring and general construction
MDF: characteristics

• MDF – Medium Density Fibreboard
  – Average density: 700 – 800 kgm\(^{-3}\) (typical target 780 kgm\(^{-3}\))
  – Core density: 600 – 700 kgm\(^{-3}\)
  – Face density: 1000 – 1100 kgm\(^{-3}\)

• Generic term for a range of dry formed fibreboards all produced in a similar way:
  – HDF: Above 800 kgm\(^{-3}\)
  – LDF: Below 650 kgm\(^{-3}\)
  – ULDF: Below 550 kgm\(^{-3}\)

• Produced in a range of thicknesses from “thin” (<2 mm) up to 60 mm
Medium Density Fibreboard

(Source: Emeri Enterprise Co., Ltd.)
MDF

- First made when fibre produced for wet formed hardboard was processed as particleboard
- Good machining and strength properties ensured that MDF rapidly became popular
- Technical developments such as “blowline blending” in the 1980’s spurred production
- Competition with particleboard manufacture has led to developments in both sectors
Other wood-based panels

• Other fibre boards
  – Insulation boards (soft board)
  – Hardboard

• Cement bonded boards
Structural panels and engineered wood
Engineered wood

• Similar to other wood-based composites that we have already considered (particleboard, MDF)....
• ....but the term “engineered” implies some real structural function

• Products include:
  – Glulam (glue laminated timber)
  – Cross-laminated timber (CLT)
  – Laminated veneer lumber (LVL – Kerto)
  – Plywood
  – Oriented Stand Board (OSB)
  – Others:
    • Parallel Strand Lumber (PSL)
    • Laminated Strand Lumber (LSL)
    • Oriented Strand Lumber (OSL)
Glulam

- Glue laminated timber – “glulam” is made by composing a number of individual wood laminations that have been specifically selected and positioned in the glulam beam, based on their performance characteristics.
- The “lams” are bonded together with durable, moisture-resistant adhesives, such as PRF – Phenol Resorcinol Formaldehyde, RF – Resorcinol Formaldehyde, MF – Melamine Formaldehyde, MUF/MURF – Melamine Urea Formaldehyde/Melamine Urea Resorcinol Formaldehyde.
- Glulam is available in depths from 15 to 180 cm (or more) and lengths of up to 30 m.
- To obtain lams of sufficient lengths, individual stress-graded pieces can be finger jointed to form a continuous length.
Applications

• Glulam allows much flexibility in design – curved beams of long length
• Connections: bolts or dowels
Applications

(Source: MetsäWood)
Moisture

(Courtesy: Prof. Stefan Winter)

(High moisture content; inappropriate resin – UF)
Cracking

(Courtesy: Prof. Stefan Winter)

Curved beams – tension perpendicular to the grain
Delamination

Glulam de-lamination and old repairs exposed

(Source: TRAC Structural Ltd)
CLT

- CLT or Cross-Laminated Timber
- Made from stress graded (C24/C16 softwood) bonded together with alternate layers laid perpendicular to the adjacent layer
- Binderholtz panel production [http://www.youtube.com/watch?v=bb-TOnLDmoE&feature=related](http://www.youtube.com/watch?v=bb-TOnLDmoE&feature=related)
- [http://www.youtube.com/watch?v=rLqiwBL28v4](http://www.youtube.com/watch?v=rLqiwBL28v4)
Applications

- Structural applications
- Walls, roofs, floors
- Massive timber, so advantages in terms of thermal and sound insulation
- Thermal mass and moisture buffering effects
Laminated veneer lumber - LVL

- LVL forms a group of materials/products known as structural composite lumber. These include, LVL, parallel strand lumber (PSL), laminated strand lumber (LSL) and oriented strand lumber (OSL)
- LVL is formed from rotary cut veneers that are aligned mainly parallel to each other
Metropol parasol – Sevilla
Other structural composite lumber

- Parallel strand lumber: formed from long veneer strands around 25 mm wide, glued together to form long beams with good structural properties
- Laminated strand lumber and oriented strand lumber are formed from stands (see later for description of stranding) that are from 15 cm (OSL) to 30 cm (LSL) in length.
PSL: structural applications similar to LVL
Oriented Strand Board - OSB

- OSB- Oriented Strand Board is an engineered wood product manufactured from strands of wood several centimetres in length and width, but < 1 mm in thickness
- Strands are “oriented” in a similar manner to plywood
- Bonded with durable waterproof resins such as phenol formaldehyde (PF) or MDI (methylene diphenyl diisocyanate)
- The combination of long, interleaved strands of wood, which are preferentially oriented, give structural properties to the panel
Applications

• Substitute for plywood:
  – Good mechanical properties
  – Low density → good specific mechanical properties
  – Raw material: good availability; typically lower quality than necessary for plywood; good utilisation of resources

• Available in different grades depending on application, e.g.
  – For dry structural applications, or for dry and humid structural use (e.g. [http://www.norbord.com/SterlingOSB_Splash.shtml](http://www.norbord.com/SterlingOSB_Splash.shtml))

• Typical applications include:
  – Construction (components for I beams, sheathing, flooring, internal walls, roof decking)
  – Interior applications (e.g. shop-fitting)
  – Industrial applications (agricultural buildings)
  – Concrete moulding (shuttering)
  – Furniture
Oriented strand board (OSB)

(Source: TRADA)
Further reading and resources

• General information:
  – APA: The Engineered Wood Association (http://www.apawood.org/)
  – Structural Board Association (http://www.osbguide.com/)

• Manufacturers:
  – Kronospan
  – Egger
  – Norboard

• European Panels Federation (http://www.europeanpanels.eu/)

• Wood-based Panels: An introduction for specialists

• Wood-based panels international
Further reading and resources

- Effect of process, strand geometry and orientation: