Engineered wood products

- Driving innovation in wood products manufacturing
Learning objectives

- Understand what EWP are:
  - How they are manufactured
  - Categories & uses
  - Benefits and disadvantages
  - Future market expectations
  - Impacts on forestry
Engineered wood products (EWP)

- **Definition:**
  - A group of structural wood products that are *manufactured* to *specific performance standards*

- **Rationale & advantages**
  - Nature has optimized wood for growing trees, not for producing lumber
    - variable properties
    - solid wood is anisotropic
  - EWP provide greater uniformity, reliability and resource efficiency than lumber
  - Uniform MC, no knots
  - Available in large sizes
    - preferred by architects
  - Less wastage at construction site
Disadvantages of EWP

- Higher per-unit cost than lumber
  - On a comparative lumber size basis
  - May not be more expensive on a comparative use basis

- Thin strand-based products may have poorer thickness dimensional stability than lumber

- More complex manufacturing processes require larger initial capital investment
  - Usually offset by using lower cost fibre inputs
EWP Categories

1. Lumber-based EWP
   • 1.1. Glue-Laminated Timber (Glulam)
   • 1.2. Cross Laminated Timber (CLT)

2. Veneer-based EWP
   • 2.1. Laminated Veneer Lumber (LVL)
   • 2.2. Parallel Strand Lumber (PSL)

3. Strand-based EWP
   • 3.1. Laminated Strand Lumber (LSL)
   • 3.2. Oriented Strand Lumber (OSL)

4. Other
   • 4.1. I-Joists
   • 4.2. Finger jointed lumber
EWP markets

- EWPs compete with lumber, concrete and steel in specific market niches
  - Usually where consistent performance & ease of installation are important

- Becoming more widely used

- Three major markets
  - Residential
  - Non-residential
  - Civil engineering infrastructure
1: Lumber-based EWP

Photo source: Unalam
1.1: Glue-Laminated beams (Glulam)

Glulam

- Oldest EWP – dates from mid 1800’s
- Produced by face laminating lumber to form beams
- Individual lamina are usually 19 to 38 mm (0.75-1.5 inches) thick
- Glulam beams can be
  - larger in cross section compared to solid timber
  - curved and tapered
  - used in wide span applications
    - compete with steel or concrete beams
    - e.g. hockey arenas, swimming pools, churches, warehouses, hospitals, bridges, universities
Glulam

- Production is **labour intensive**
  - Commodity manufacture can be automated
- Individual boards finger-jointed provide length needed for lamina
- Each lamina stress tested and planed produce a fresh surface for gluing
  - Strongest material placed on the outer faces of beam (compression and tension)
  - Weaker material placed on beam interior
Glulam manufacture

- Cold curing waterproof resin (usually PF or PRF) applied to each lamina using glue spreader
- Beams are then pressed together, placed on forms and held in place by movable clamps until the glue cures
- Finally beams are surface planed, sanded and drilled/finished to meet the design requirements
- Can be pressure treated when required with fire retardant or wood preservative

http://www.youtube.com/watch?v=3R2s2rsp1r4&feature=player_embedded
http://www.youtube.com/watch?NR=1&v=PnHQRhFnveM&feature=endscreen
Glue-Laminated Timber

- On weight basis cost of Glulam is 2x to 3x solid wood due to:
  - High value raw material
  - Manufacturing is labor intensive
    - Only commodity-based standard beams can be automated
  - Structural adhesive is one of the most expensive in industry and high spread rates are used
    - Use 340 g/m², 2x that for plywood or LVL

- Greater strength & stiffness than lumber
- Stronger than steel on a weight basis
North American Glulam uses and production (UN ECE 2013)

US Glulam end uses 2011
- Residential construction 42%
- Non-residential construction 51%
- Industrial/other 7%

Glulam Production
- US
- Canada


Glulam Production (1,000 m³)
- US: 709
- Canada: 313
- US: 34
Heavy frame timber using glulam beams (up to 10 stories)

Concrete cores to resist lateral loads

Glulam post & beam
1.2: Cross Laminated Timber (CLT)
Cross Laminated Timber

- Multi-layer panel with crosswise arrangement of lamellae (usually 3-7)
  - As for plywood but graded lumber used
  - Lamellae glued & pressed

- Common dimensions
  - Thickness: three to seven layers
    - 75 - 400 mm (3 - 16 in.)
  - Width: 600 mm to 2.4 m (2 - 8 ft.)
  - Length: up to 20 m (64 ft.)
  - Span: up to 7.5 m (24 ft.)

Source: FPInnovations
CLT manufacturing
(FPInnovations 2011)

1. Primary lumber selection
   - MC check
   - Visual grading
   - E-rating (optional)

2. Lumber grouping

3. Lumber planing

Secondary lumber preparation

4. Lumber/layers cutting to length

5. Adhesive application

6. Panel lay-up

7. Assembly pressing

8. CLT on-line quality control, surface sanding and cutting

9. Product marking, packaging and shipping
CLT adhesive application
(FPIInnovations 2011)

- **Adhesives**
  - Phenol resorcinol formaldehyde (PRF)
  - Emulsion polymer isocyanate (EPI)
  - One component polyurethane (PUR)

- **Applied in parallel lines**

- **Application rates & press times dependent upon adhesive**
CLT panel lay up (FPInnovations 2011)

- **Wood**
  - Usually graded structural lumber
    - Major direction = No. 2 & better
    - Minor direction = No. 3 & better
  - May add other product in minor direction
    - OSB, LVL etc

![Diagram of CLT panel lay up]

Generic CLT

Hybrid CLT
CLT Pressing, Grading/Sanding
CLT Machining & storage
Transport & assembly

http://www.youtube.com/watch?v=rLqiwBL28v4&feature=related
UBC Earth Sciences Building
(Photo: Structurlam)
Forte, Lend Lease Building, Melbourne, Australia

- Completed in Dec 2012
- 10 stories
  - Podium = concrete
  - Upper 9 stories CLT
  - Currently tallest wooden residential building in world
- CLT benefits (compared to steel & concrete):
  - Lighter
  - Excellent acoustic properties
  - Rapid construction
  - Low GHG footprint

[http://www.youtube.com/watch?v=cqXygHyU5ws](http://www.youtube.com/watch?v=cqXygHyU5ws)
Library & Community Centre, Melbourne

- Same development company as Forte
- Highest level of ‘green building’ in Australia
- Three-storey building 55m long x 18m wide
- CLT and Glulam beam construction
- CLT made in Austria & shipped to Australia
- Construction started April 2013
- Estimated building time 6-8 weeks
- Project completion in late 2013


2: Veneer-based EWP
2.1: Laminated veneer lumber
Laminated veneer lumber (LVL)

- Like Glulam, LVL uses continuous lamina
  - Lamina are sheets of veneer rather than lumber in Glulam
  - Lamina thickness = 1.5 – 6 mm (0.06-0.25 ins)
  - Density = that of its veneers
  - Dimensions = those of standard lumber

- Benefits compared to lumber:
  - Wood defects are randomized
  - Grain parallel to long direction (unlike plywood)
    ⇒ strength properties > glulam & stress graded lumber
    ⇒ also more uniform (narrower SD)
LVL compared to plywood

Source: CWC 2012
LVL production process

- [YouTube video](http://www.youtube.com/watch?v=qASxDjoRtSo&feature=related)
- Production parallels that of plywood
  - Sorting of the veneers is automated
    - ultrasound used to select for density (proportional to strength)
  - Sorting is important to give uniform products
- Large billets (1.2 m wide by 24 m long) of veneer built up on a moving belt by alternately adding veneer and glue
- Cold press before final hot press using radio frequency (RF) energy presses – reduces press times from 20 min. in regular press to 5 min.
Laminated veneer lumber

- Softwood usually used (southern pine, Douglas-fir, spruce, hemlock)

- Adhesives
  - waterproof Phenol-Formaldehyde (PF) most common
  - Application rate about 180 g/m²

- Cost: LVL >> solid wood

- Advantages:
  - Uniform MC, resistance to warp, high & uniform strength and long lengths
LVL header applications
North American LVL uses and production (UN ECE 2013)

LVL end uses
- Header/Beam 64%
- I-Joist 29%
- Rim board 2%
- Industrial 5%

Markets
- ~ 80% in new homes

LVL Production
- US
- Canada
2.2: Parallam (or PSL)
Parallam (or PSL) manufacture

- Produced from long strands of veneer from Douglas-fir, southern pine or yellow poplar
- First veneer from logs is usually not continuous due to taper
  - PSL uses waste product from veneer, plywood and LVL mills
- Veneer put through clipper and trimmer to make long strands needed for PSL
  - Strands approx 20mm wide, 4 mm thick and up to 1 m long
Parallam manufacture

- Strands dried to 3 – 5% MC
- PF resin applied – up to 15% by weight
- RF or microwave energy used to cure resin in a continuous “caterpillar” press
  - 25 x 25 cm billets cured in few minutes
- Billets sawn to any size - alternative to softwood timber
  - Especially larger beams
  - Also competes with LVL and shorter glulam beams
Parallam (or PSL)

- Density increased slightly by pressing so strength higher than best grades of Douglas fir or Southern pine
- Has uniform strength
  - Slightly higher bending stress than LVL
- High void volume makes preservative treatment easy
  - Enables exterior applications
3: Strand-Based EWP

Source: Louisiana Pacific
Strand-Based Composite Lumber

- Produced by gluing and pressing wood strands or flakes into lumber substitutes
  - More consistent product attributes than lumber – strength, warp, MC
  - Allow large sizes of ‘lumber’ to be produced from small logs
  - Usually made from cheap, low density hardwoods (aspen, yellow poplar)
  - Higher product yield compared to a lumber mill
    - More m$^3$ product/m$^3$ roundwood
  - Takes pressure off (mature) forest resources
3.1 Laminated strand lumber (LSL)
Laminated strand lumber (LSL)

Similar to Parallam except:

- Made from strands **not** cut veneer
- Strands are thinner and wider
  - Like OSB strands but 2x as long (30 cm) & 2-5 cm wide
- Different resin is used
  - pMDI (polymeric diphenylmethane diisocyanate)
  - Used for rapid curing
LSL Manufacture

- Logs debarked (usually fast growing hardwoods)
- Strands produced by disk flaker
- Dried (to 2-5 %MC)
- Screened to remove broken & fine strands
- Blended with pMDI resin
- Can add wax for water repellency
- Formed into mat – strands not fully aligned
- Billets (25-150 mm thick) cured in steam press
  - Cured in minutes
- Cut to desired dimensions
LSL applications

- Competes with solid wood in high grade structural applications
  - beams, headers, rim boards and structural framing lumber
- straighter, stronger and can handle longer spans.
- more consistent moisture content than lumber
  - minimizes twisting, warping and shrinking
Oriented strand lumber (OSL)

- Newest of the composite products
- Made from oriented flakes
  - like LSL/OSB but strands all aligned along billet
- Flakes are shorter (by 50%) than LSL
  - ~ 15 cm same as OSB
- Competes with LVL, LSL and large lumber
  - headers for windows, doors
OSL applications (Ainsworth 2011)
4: Other EWP

Flange

Web
4.1: I-Joists (aka I-beams)

- Early I-joists used solid wood and plywood for web
- Plywood now replaced by OSB
- LVL now used in place of solid wood
- Very long joists possible but handling generally limits length to 25 m
- Web can be made fire-resistant by layer of gypsum

[http://www.youtube.com/watch?v=R4-orETdkgA](http://www.youtube.com/watch?v=R4-orETdkgA)
I-Joist markets (UN ECE 2011)

Markets

- New single & multi-family homes
  - Raised floors
- 2011: 52% share of SF home raised flooring market
- 1998: share = 31%
- 1992: share = 16%

New residential floors 72%
Remodelling 5%
Non-residential 18%
New residential roofs & walls 5%
North American I-joist production (UN ECE 2013)
4.2: Finger-jointed lumber
Finger-jointing

- Used to join pieces of wood by their ends
- Often used to remove defects from wood or to provide an “endless ribbon” of sawn wood for products such as Glulam, CLT
- Strength of joint depends on length and pitch of fingers and adhesive used
Market developments - EWP

- North American residential housing market is most important for all EWP categories except 1
  - ??
- What has been happening in this market
US housing starts
(US Census Bureau 2013)

Average = 1.48

2005 = 2.07

2012 = 0.830
Average area of US houses
(US Census Bureau 2013)

Finished Floor Area (square feet)

- **Single Family**
  - 1950 = 1,061
  - 2012 = 2,505

- **Multi-Family**
  - 1950 = 1,138
  - 2012 = 1,138
US house area constructed annually
(US Census Bureau 2013)

Floor area constructed annually (million ft\(^2\))

Total

2005=4.63

2012=1.65

Single Family

Multi-Family
Consumption changes/consumed/m² constructed between 1985-2008:
- 41% reduction in lumber
- 83% increase in EWP and panels
Growth Potential for EWP
(adapted from APA 2012, LP 2013)

North American framing market 2012

- Lumber 66%
- LVL & I-joist 29%
- Strand EWP 5%

50% suitable for EWP

The “LP EWP House”
A Quality Alternative to Lumber
EWP often have higher yields and use lower quality species

- We can increasingly engineer in product attributes rather than having to grow great fibre

- Compare by use:
  - Lumber: Lumber, LVL & Timberstrand (LSL/OSL)
  - Panels: Plywood & OSB
  - Beams: Glulam & Parallam (PSL)

- Implications for forestry
  - See homework

![Bar chart showing typical product yield (kg product/kg roundwood)](chart.png)
### Impact of EWP on harvest volume and roundwood quality?

1. Process yield affects RW required to meet market demand
2. Fibre quality affects RW type and cost

<table>
<thead>
<tr>
<th>Category</th>
<th>Product</th>
<th>Volume</th>
<th>Quality</th>
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<tbody>
<tr>
<td>Lumber</td>
<td>Lumber</td>
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<tr>
<td></td>
<td>2.1 LVL</td>
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<td></td>
<td>3.1 LSL/3.2 OSL</td>
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<td></td>
<td>1.2 CLT</td>
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<td>Panel</td>
<td>Plywood</td>
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<td></td>
<td>OSB</td>
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<tr>
<td>Beam</td>
<td>1.1 Glulam</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>2.2 PSL</td>
<td></td>
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</tr>
</tbody>
</table>
EWP often require less use of wood fibre in construction (Schuler 2004)

- **Conventional flooring system**
  - 85 2x10’s; 133 pieces total
  - 2700 bd ft/house
  - 1.3 million single family houses consume 3.5 BBF/yr

- **I joist system**
  - 26 I joists; 80 pieces total
  - Overall 50% savings in wood fibre
  - Reduce consumption by 1.75 BBF timber/yr
  - Roundwood harvest reduction: 8.3 million m³.
Bamfield Marine Center
Bamfield, British Columbia
Take home concepts

- **EWP driving innovation in manufacturing & construction**

- **EWP produce more from less**
  - High performance products from reduced volumes of lower quality inputs
  - Can engineer product attributes rather than depending on natural fibre quality
    - Less dependent upon natural resource attributes
    - Require cheaper fibre inputs due to higher manufacturing costs

- **EWP taking market share from lumber**
  - Lumber will dominate SF/MF home construction for foreseeable future

- **Large CLT potential in high rises**
Homework:
1. EWP and innovation in construction
   1. Michael Green: Ted talk - Wooden High Rises
      - http://video.ted.com/talk/podcast/2013/None/MichaelGreen_2013.mp4
   2. Leander Bathon: Earth Sciences Building at UBC
      - http://www.youtube.com/watch?v=9Z95EhBo9ZY
   3. Hubert Rhomberg: CREE buildings, Austria
      - http://www.youtube.com/watch?v=ZpBfXZ5tKdk&list=PL85Gt5s9miEfwC5kV-WChZx70GQCOdNG3

2. Assignment: Impact of technological developments on roundwood demand