Properties of timber

Mahes Rajakaruna

FWPRDC/NTDC
TIMBER EDUCATION PROGRAM
Timber grows on trees

Native Karri forest  WA
Hardwood
Diverse species

Radiata Pine plantation  SA
Softwood
Single species
Environmental issues

- **In an untouched native forest**
  - growing trees absorb $\text{CO}_2$ from atmosphere
  - decaying trees release $\text{CO}_2$ to the atmosphere
  - $\text{Carbon in} \approx \text{Carbon out}$

- **In managed forests, plantations**
  - growing trees absorb $\text{CO}_2$ from atmosphere
  - mature trees are removed and new trees planted
  - $\text{Carbon in} > \text{Carbon out}$
Growing and harvesting timber - beneficial to the environment

- Low energy of production
- Carbon stored in timber away from atmospheric cycle

Managed Forests
- Plantations - single species farmed for timber
- Native forests managed for many uses
  - species conservation / biodiversity
  - water and timber harvesting
  - education and recreation
Hardwoods and Softwoods

- **Hardwoods**
  - broad leaf
  - generally higher densities
  - often dark in colour

- **Softwoods**
  - needle-like leaves
  - generally lower densities
  - often light in colour

Native Australian hardwood include:
- mountain ash
- brown box
- spotted gum
- jarrah

Common Australian s’wds include:
- radiata pine
- cypress pine
- hoop pine
- douglas fir
Cross section of a tree

- **Annual Growth rings**
- **Gum Vein**
- **Internal check**
- **Pith**
- **Heartwood**
- **Sapwood - small for most Hardwoods.**
- **Bark**
- **Back sawn**

**Shrinkages from green to 12% mc:**
- T Tangential 10%
- R Radial 5%
- L Longitudinal 0.1%
Sapwood and Tree Growth

- **Cambium** -
  growth layer - new wood laid down on outside of tree

- **Sapwood** -
  - transfers water and nutrients from roots to leaves
  - less dense, lighter colour, cell wall thickness increasing
  - susceptible to attack - treatment required

*(Allowed in some species of commercial timber)*
Heartwood

- **Heartwood** -
  - cells no longer growing
  - extractives (growth by-products) can provide protection from attack

- **Core** - (juvenile wood)
  - oldest wood
  - at centre - contains pith
  - laid down when tree young
  - can be damaged by tree pre-stress during growth
Performance of Timber

- **Appearance**
  - Grain and colour
  - Feature
  - Dimensional stability & emc%

- **Structural**
  Essential e.g. strength and stiffness
  Utility e.g. dimensional stability - shrinkage/emc
  Straightness - bow, spring, cup and twist

- **Durability**
  Biological hazards
  Natural resistance / treatment
Microstructure of Timber

- Cells - fibres - mainly longitudinal orientation
- Bound together with rays
- Higher strength and stiffness parallel to grain
- Vessels are only seen in hardwood
Composition of cells

- **cellulose**
  - long chain polymer with cells principally aligned with the axis of cell
  - very effective in transmitting tension or compression

- **lignin**
  - serves as a bonding agent which glues the cells together

- **hemicellulose**
  - binds cellulose to the cells
Direction of Strength & Stiffness

Strong parallel to grain & Stiff parallel to grain

Weak perpendicular to grain
Moisture in Wood Cells

- Unseasoned timber
- Partially seasoned timber
- Seasoned timber

Growing tree:
- Free water
- Bound water
- Fibre saturation

100%
25%
15%
Moisture in Timber

- **Moisture content** \((mc)\)
  - in growing tree - \(mc = 50\%\) to > 100\%
  - felled tree - \(mc\) begins to decrease

- **Fibre saturation point** \((fsp)\) (~25\%)
  - above \(fsp\) - moisture in cell cavities lost
    - \(\rightarrow\) little change in dimension
  - below \(fsp\) - moisture in cell wall lost
    - \(\rightarrow\) shrinkage perp to grain

**Seasoning** - process of removing moisture from timber
  - Kiln drying (steam, LPG gas, solar)
  - Air drying
  - Other - chemical, microwave.
Equilibrium moisture content (emc)

- Wet atmosphere / Dry wood $\rightarrow$ moisture moves to wood

- Dry Atmosphere / Wet wood $\rightarrow$ moisture moves from wood

- Wood at emc $\rightarrow$ no moisture movement

Indoor air conditioned: 8% - 10%
Indoor heated: 8% - 12%
External - coastal: 14% - 18%
External - inland: 10% - 15%
Seasoning

- **Seasoned timber:**
  - $mc < 15\%$ - close to $emc$ indoors
  - will shrink & swell slightly as humidity changes

- **Everything else:**
  - sold as unseasoned timber
  - shrinks on further drying

**Effect of $mc$ on properties:** reducing $mc$ causes
- an increase in
  - strength
  - stiffness (reduced creep)
  - durability (reduced risk of attack)
  - effectiveness of coatings

A decrease in dimensions $b$ & $d$ (shrinkage mainly perp. to grain)
Shrinkage

- Loss of moisture in range mc <25%
- Reduction in cell wall thickness
- Reduction in cross-sectional dimensions

<table>
<thead>
<tr>
<th>Hardwood Softwood</th>
<th>Shrinkage from 25% to 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiata Pine</td>
<td>Rad 3.5% Tang 4%</td>
</tr>
<tr>
<td>Hoop Pine</td>
<td>Rad 2.5% Tang 3.5%</td>
</tr>
<tr>
<td>Cypress</td>
<td>Rad 3.5% Tang 4%</td>
</tr>
<tr>
<td>Spotted Gum</td>
<td>Rad 4.5% Tang 6%</td>
</tr>
<tr>
<td>Karri</td>
<td>Rad 4.5% Tang 10%</td>
</tr>
<tr>
<td>Sydney Blue Gum</td>
<td>Rad 5% Tang 9%</td>
</tr>
<tr>
<td>Grey Iron Bark</td>
<td>Rad 5.5% Tang 7.5%</td>
</tr>
<tr>
<td>Mountain Ash</td>
<td>Rad 6.5% Tang 13%</td>
</tr>
</tbody>
</table>

Specify correctly Detail to avoid problems
Duration of Load - Creep

Creep (extra deformation under load)
- recoverable - deformation slowly comes out after load removed
- irrecoverable - deformation remains after load removed
- function of moisture movement, magnitude & duration of load
- occurs at all loads
- important when calculating deflections of beams
Application dictates selection of ‘clear’ vs ‘feature’

Natural growth characteristics

- **Natural Growth Characteristics**

  - **Appearance enhanced** - timber shows its character
  - **Strength decreased**: dependent on size and location of characteristic
    - **Knots** - part of a branch extending from pith
    - **Checks** - small surface cracks, often caused in drying
    - **Included bark** - pockets with no wood fibres
Natural features in Sawn Timber

Knots
contain weak juvenile wood,
cause slope of grain @ edge

Slope of grain
esp. at edges - low strength
perp. to grain decreases strength at angle to grain
Natural features and properties

- **Knots**
  - discontinuity of grain at edge
  - cause slope of grain at an edge
  - often reduce strength and stiffness

- **Gum and resin veins**
  - less connection across grain
  - lower shear strength and stiffness

- **Checks**
  - less connection across grain
  - reduced shear strength and stiffness

- **Pith and core wood**
  - contain weak juvenile wood
Processing Sawn Timber

- Trees are prestressed
- Cutting boards from trunks causes stress relief & slow change in shape of boards
- Bent trees can cause slope of grain in products
- Spring is a problem for all timber
Evaluation of Structural Properties

- **Small clear specimens** - data only reflects wood fibre strength

- **In-grade testing** - commercial sized timber under realistic loading conditions

- **Commercial timber**
  - tensile strength < compression strength
  - tensile failures - splintery, brittle, sudden, loud
  - compression failures - wrinkles, ductile, slow, quiet
‘Viking Ship’ Lillehammer Norway

- Large span of trusses
- Large glulam material used
- Innovative connections
- Design and fabrication team
Timber Behaviour

Unique behaviour (strength parallel to grain)
Unique appearance (life, character, warmth)
Unique structure (parallel cells, growth)

Manufactured wood products
• made from wood to maximise the effect of high strength parallel to grain
• can still be used for appearance applications
• quality control in manufacture can give very reliable properties

Larger members can be manufactured from many smaller cross-section pieces

Limits on size of sawn timber
Limits on size of trees felled
Manufactured products

Used for:
- large spans - deep beams
- large cross-sections - large span truss elements
- panel members - bracing, architectural
- large panel elements - floor, roof, ceiling cladding (minor axis bending)

Includes:
- LVL
- Glulam
- Plywood
- Others
LVL  Laminated Veneer Lumber

- made from laminating thin sheets of wood
- most laminates in longitudinal direction
- very deep and long sections possible
- high strength

Laminates prior to gluing and pressing

Final LVL sheet
grain in all laminates
Glulam

Glued laminated timber

- made from gluing many small pieces together to form deep member
- Strength > individual pieces
  - potential weakness - finger joints
- opportunities for creative architectural use
- curved, tapered beams
Glulam Portals Jellie Park Pool NZ

- Timber suited to swimming pool environments
- Attention to connections
Plywood

- made by gluing and pressing thin laminates together to form a sheet
- grain in laminates in alternate directions - strength in two directions
- select face material for appearance products & glues for environment, durability
  - panels (decorative or bracing)
  - sheets - plate bending (flooring, formwork)
  - webs (I-beams, box beams)
Other manufactured wood products

**I-beam**  
- timber/LVL flanges, plywood webs  
- lightweight, suitable for udl's on medium spans

**Box beams**  
- timber/LVL flanges, two plywood webs  
- suitable for larger spans, torsionally stiff, can use decorative plywood

- **Timber flanged steel web joists**  
  
  lightweight, open webs give access for service  
  webs by light tubes, solid rounds, corrugated sheets
Grading

Sorting of products into groups with similar characteristics and properties

Sorting Criteria

- Appearance grade
- Structural grade

Specify product by calling up a specific grade.
Appearance Grading

Criterion for sort is appearance of timber surface

- Classification of timber used for
  - furniture
  - joinery and architectural trim
  - decorative building products

- Grading rules
  - knot size & frequency (location unimportant)
  - splits, cracks, checks (size and frequency)
  - colour, grain uniformity
  - utility - want, wane, cup, bow, spring, twist

- Feature grade
  - makes a feature of natural characteristics eg knots
Structural Grading

Criterion for sort is estimated structural properties of timber

- Used for classification of timber with defined structural properties - includes framing for housing
- May include appearance
- Each grade associated with a suite of structural properties - limit states
  - **strength** - characteristic value based on 5th %ile (conservative - involves safety)
  - **stiffness** - characteristic value close to average - realistic for most applications
Structural grading is based on correlation between strength and a grading parameter:

- **Visual stress grading** - presence or absence of natural characteristics
- **Machine stress grading** - stiffness on flat (minor axis MoE)
- **Proof grading** - ability to take a proof load. Each piece passed through machine, bending applied at about characteristic strength level. Broken pieces fail - unbroken ones pass
- **Quality control** - verification of grade properties by testing
Timber Stress Grades

- Structurally graded products need to be assigned properties for designers to use
- limited number of grade descriptions
- most versatile for sawn timber is F-grade

<table>
<thead>
<tr>
<th>Stress Grade</th>
<th>Structural properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending</td>
<td>Strength</td>
</tr>
<tr>
<td>Tension</td>
<td>Stiffness</td>
</tr>
<tr>
<td>Compression</td>
<td></td>
</tr>
<tr>
<td>Shear</td>
<td></td>
</tr>
</tbody>
</table>

High Stress grade = High strength and stiffness
Stress Grades

- Stress grade is **assigned to a package of timber**
- Stress grade **gives structural properties**
  - Each piece in a package can be taken to have those properties

Timber **stamped** with Stress grade at grading

**F-grades** - commonly used with all grading methods and with plywood

**MGP grades** - used only with seasoned pine (machine graded)

**GL grades** - used only for glulam members

**LVL** - each manufacturer assigns own grade & design properties
Structural grading

Visual Stress Grading Rules

- Very different to appearance grading -
  - different characteristics are important
  - different sizes & location of each feature are allowed

- Each piece of timber examined by a trained grader for characteristics known to decrease strength, stiffness or utility
  - knots - size, location, angle and position in relation to others
  - slope of grain - on each face or edge
  - splits and checks

(Checks that may be important to appearance grading may not be important here)
Visual Stress Grading

For each species, Tables assign an F-grade to each of the structural grades. An F-grade may be stamped on each piece.

eg. For Structural #3 seasoned jarrah, F14 is stamped onto each piece.
For Structural #3 seasoned (imported) SPF, F7 is stamped on each piece.
Machine stress grading

Relies on correlation between a measured structural property and all others

Minor axis \( E \) most commonly used

- each piece tested in non-destructive bending about minor axis over most of the length
- minimum \( E \) value determines grade (MGP grade) of whole piece
- grade stamp often automatically applied by the machine (visual check after grading can over-ride machine grade stamp to downgrade piece)
Proof Grading

Grade verification technique
Timber initially sorted using a documented process

Significant major axis bending load applied

Grade verified
Pieces sold as Proof graded timber

If too many pieces fail, producer must adjust initial sorting process
Durability

**Biological/Physical Hazards**
- Weathering
- Fire
- Chemical

**TIMBER**
- Species
- Natural durability of heartwood

**Design Detailing**
- Minimises exposure to hazards

**Treatment**
- Enhances durability of sapwood

**Maintenance ensures protection remains functional**

- Fungi
- Termites / borers
- Marine
Biological/Physical Hazards

- **Weathering** - protection from moisture, sun
  - sealants (including paint)
  - shading (positioning in structure)
- **Fire** - protection
  - sprinkler systems (active)
  - insulation eg. fire-rated plasterboard (passive)
  - oversized members allow loss through charring (passive)
- **Chemicals** - timber performs well relative to steel/concrete
  - resistant to degradation for pH>2 and pH<10
  - softwoods marginally better than hardwoods
- **Fungi**
- **Termites/borers**
- **Marine organisms**
## Hazard Levels

<table>
<thead>
<tr>
<th>Hazard Class</th>
<th>Exposure</th>
<th>Service Conditions</th>
<th>Biological Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Inside above ground</td>
<td>Fully Protected Well ventilated</td>
<td>Borers Only</td>
</tr>
<tr>
<td>H2</td>
<td>Inside above ground</td>
<td>Protected from Wetting nil leaching</td>
<td>Borers and Termites</td>
</tr>
<tr>
<td>H3</td>
<td>Outside above ground</td>
<td>Moderate wetting and leaching</td>
<td>Decay borers &amp; termites</td>
</tr>
<tr>
<td>H4</td>
<td>Outside in ground</td>
<td>Severe wetting &amp; leaching</td>
<td>Severe decay, borers &amp; termites</td>
</tr>
<tr>
<td>H5</td>
<td>Ground contact</td>
<td>Extreme wetting, leaching &amp;/or critical use</td>
<td>Very severe decay, borers and termites</td>
</tr>
<tr>
<td>H6</td>
<td>Marine waters</td>
<td>Prolonged immersion in sea water</td>
<td>Marine wood borers and decay</td>
</tr>
<tr>
<td>H6SW</td>
<td>Marine waters</td>
<td>Prolonged immersion in sea water</td>
<td>Marine wood borers and decay</td>
</tr>
</tbody>
</table>

**H Classes**

- **H1 least hazardous**
- **H6 most hazardous**
# Natural Durability (Heartwood)

Extractives and growth characteristics affect natural durability of timber species.

<table>
<thead>
<tr>
<th>Class</th>
<th>Durability</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Highly durable</td>
<td>Ironbark, Tallowwood, Cypress, Turpentine, Forest red gum</td>
</tr>
<tr>
<td>2</td>
<td>Durable</td>
<td>Spotted gum, Blackbutt, Western cedar, River red gum, Stringy bark (yellow &amp; white)</td>
</tr>
<tr>
<td>3</td>
<td>Moderately durable</td>
<td>Brush box, Rose/flooded gum, Sydney blue gum, Silver topped stringybark</td>
</tr>
<tr>
<td>4</td>
<td>Non-durable</td>
<td>Douglas fir, Hoop pine, Radiata pine, Mountain ash/ Tasmanian oak, unidentified timbers</td>
</tr>
</tbody>
</table>
Long-term Performance of Timber

Can match natural durability with environmental hazard to estimate long-term performance of untreated timber heartwood

<table>
<thead>
<tr>
<th>Natural Durability Class</th>
<th>Heartwood Service Life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H1 Fully Protected</td>
</tr>
<tr>
<td>Class 1</td>
<td>50+</td>
</tr>
<tr>
<td>Class 2</td>
<td>50+</td>
</tr>
<tr>
<td>Class 3</td>
<td>50+</td>
</tr>
<tr>
<td>Class 4</td>
<td>50+</td>
</tr>
</tbody>
</table>
TREATMENTS

All treatments use and dispose of timber correctly. Penetration of heartwood is limited, better penetration through ends.

CCA
- ‘wet’ process
- timber needs to be redried
  - greenish appearance

LOSP
- timber mc unchanged
- dimensional stability
  - clear
  - limited water repellency
  - difficult to glue
TREATMENTS - penetration

Good penetration of sapwood
Poor penetration of most heartwood

Treated round log

Treated sawn section
DESIGN PRINCIPLES FOR DURABILITY

- **Isolate timber from insects**
  - for termites, chemical barriers / physical barriers between ground and timber

- **Protect timber from water**
  - fungi require moisture content of wood >20%
  - swelling, shrinkage can cause cracks

- **Protect timber from heat**
  - direct sunlight can cause excessive drying, shrinkage
  - direct sunlight breaks down wood / cellulose
ISOLATE TIMBER FROM PESTS

- **Barriers**
  - no direct path from ground to timber
  - chemical / physical

- **Inspect**
  - barriers can be penetrated or bridged
  - inspect barrier for signs of penetration (galleries)
  - inspect wood for signs of infestation (galleries)
SLAB BARRIERS
monolithic slabs and mesh

Monolithic slab

Mesh
SLAB BARRIERS
graded stone and reticulated chemicals
PROTECT TIMBER FROM WATER

- Protect timber from rain
  - good paint/Copper Napthanate seal
  - caps
  - roofs/verandahs

- Protect important timber from ponded water

- Elevate timber posts above water

- Detail connections to avoid trapped water
PROTECT TIMBER FROM WATER

simple detailing is better!
PROTECT TIMBER FROM WEATHERING

*Hot sun can dry timber, cause shrinkage, cracking.*

- use top quality paints, stains, water repellents
- opaque systems work best
  - light colours cooler, less weathering
- repair & maintain paints, seals regularly
  - clear finish stains: 3 - 5 year maintenance
  - light colour paints: 7 - 10 year maintenance
- see detailing for protection from water
EXPOSED MEMBERS

**Grade** - fewest inclusions, splits, nicks in upper surface

**Orientation** - heart towards bottom

**Glues** - *must* use/specify exterior glues

**Moisture content** -
- protect from moisture if possible
- seasoned products close to equilibrium for most of Aust.
- allow for shrinkage when using unseasoned timber

**Size** - minimise surface area