Timber Construction

- studs, beams
- floor diaphragms & shear walls

Timber Construction

- all-wood framing systems
  - studs, beams, floor diaphragms, shearwalls
  - glulam arches & frames
  - post & beams
  - trusses
- composite construction
  - masonry shear walls
  - concrete
  - steel

Timber Construction

- glulam arches & frames
  - manufactured or custom shapes
  - glue laminated
  - bigger members
**Timber Construction**

- **post & beam**

- **trusses**

**Timber Construction by Code**

- **light-frame**
  - **light loads**
  - **2x’s**
  - floor joists – 2x6, 2x8, 2x10, 2x12 typical at spacings of 12”, 16”, 24”
  - normal spans of 20-25 ft or 6-7.5 m
  - plywood spans between joists
  - stud or load-bearing masonry walls
  - limited to around 3 stories – fire safety

**Timber Construction**

- **composite construction**

**Timber Construction by Code**

- **heavy timber**
  - member size rated for fire resistance
  - solid or built-up sections
  - beams spaced 4’, 6’ or 8’ apart or 1, 2 or 2.5 m
  - normal spans of 10-20 ft or 3-6 m
  - timber columns or load-bearing masonry walls
  - knee-bracing common
Timber

• lightweight: strength ~ like steel
• strengths vary
  – by wood type
  – by direction
  – by “flaws”
• size varies by tree growth
• manufactured wood
  – assembles pieces
  – adhesives

Wood Properties

• cell structure and density

Wood Properties

• load duration
  – short duration
    • higher loads
  – normal duration
    • > 10 years
• creep
  – additional deformation with no additional load

Wood Properties

• moisture
  – exchanges with air easily
  – excessive drying causes warping and shrinkage
  – strength varies some
• temperature
  – steam
  – volatile products
  – combustion
Wood Properties

- **strength**
  - allowable design loads are given with respect to direction of loading
  - wood is weakest in shear parallel to the grain
  - wood is strongest in compression and tension parallel to grain

Lumber Grading

- **light-framing**
  - construction
  - standard
  - utility
  - economy
- **structural light-framing**
  - select structural
  - no. 1, 2, & 3

Engineered Wood

- **plywood**
  - veneers at different orientations
  - glued together
  - split resistant
  - higher and uniform strength
  - limited shrinkage and swelling
  - used for sheathing, shear walls, diaphragms

- **glued-laminated timber**
  - glulam
  - short pieces glued together
  - straight or curved
  - grain direction parallel
  - higher strength
  - more expensive than sawn timber
  - large members (up to 100 feet!)
  - flexible forms
Engineered Wood

- **I sections**
  - beams
- **other products**
  - pressed veneer strip panels (Parallam)
  - laminated veneered lumber (LVL)
- **wood fibers**
  - Hardieboard: cement & wood

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Timber Elements

- **stressed-skin elements**
  - modular built-up “plates”
  - typically used for floors or roofs

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Timber Elements

- **built-up box sections**
  - built-up beams
  - usually site-fabricated
  - bigger spans

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Timber Elements

- **trusses**
  - long spans
  - versatile
  - common in roofs
Timber Elements

• folded plates and arch panels
  – usually of plywood

Timber Elements

• arches and lamellas
  – arches commonly laminated timber
  – long spans
  – usually only for roofs

Timber Elements

• beams
  – joists
  – girders

  – lateral bracing

  – deflection
    • elastic
    • creep

Approximate Depths

![Approximate Depths Chart](image-url)
Wood Design

- National Design Specification
  - National Forest Products Association
  - ASD & LRFD (combined 2005)
  - adjustment factors x tabulated stress = allowable stress
  - adjustment factors terms, C with subscript
  - i.e, bending:

\[ f_b \leq F'_b = F_b \times \text{(product of adjustment factors)} \]

Allowable Stresses

- design values
  - \( F_b \): bending stress
  - \( F_t \): tensile stress
  - \( F_v \): horizontal shear stress
  - \( F_{cL} \): compression stress (perpendicular to grain)
  - \( F_c \): compression stress (parallel to grain)
  - \( E \): modulus of elasticity
  - \( F_p \): bearing stress (parallel to grain)
Adjustment Factors

• terms
  – \( C_D \) = load duration factor
  – \( C_M \) = wet service factor
    • 1.0 dry \( \leq 16\% \) MC
  – \( C_F \) = size factor
    • visually graded sawn lumber and round timber > 12” depth

\[ C_F = \left( \frac{12}{d} \right)^{1/6} \leq 1.0 \]

Adjustment Factors

• terms
  – \( C_{fu} \) = flat use factor
    • not decking
  – \( C_i \) = incising factor
    • increase depth for pressure treatment
  – \( C_t \) = temperature factor
    • lose strength at high temperatures

Load Combinations

• design loads, take the bigger of
  – (dead loads)/0.9
  – (dead loads + any possible combination of live loads)/\( C_D \)

• deflection limits
  – no load factors
  – for stiffer members:
    • \( \Delta_T \) max from \( LL + 0.5(DL) \)
    • for instantaneous deflection
Deflection Limits

- relies on Uniform Building Code specs

<table>
<thead>
<tr>
<th>Use</th>
<th>LL only</th>
<th>DL+LL</th>
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</thead>
<tbody>
<tr>
<td>Roof beams:</td>
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<td></td>
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<tr>
<td>Industrial</td>
<td>L/180</td>
<td>L/120</td>
</tr>
<tr>
<td>Commercial plaster ceiling</td>
<td>L/240</td>
<td>L/180</td>
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<tr>
<td>no plaster</td>
<td>L/360</td>
<td>L/240</td>
</tr>
<tr>
<td>Floor beams:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordinary Usage</td>
<td>L/360</td>
<td>L/240</td>
</tr>
</tbody>
</table>

Wood Beam Design - Glulam

- find M
- determine allowable stress
  - Pinus Radiata (man.) basic working stress (MPa)

<table>
<thead>
<tr>
<th>Timberboard Glulam</th>
<th>Moisture content</th>
<th>Bending parallel P Fs</th>
<th>Compression parallel P Fs</th>
<th>Tension parallel P Fs</th>
<th>Shear in beam P Fs</th>
<th>Compression perpendicular P Fs</th>
<th>Modular elasticity E (GPa)</th>
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<tbody>
<tr>
<td>E11</td>
<td>16%</td>
<td>13.8</td>
<td>12.5</td>
<td>8.3</td>
<td>1.9</td>
<td>4.3</td>
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<td>12.1</td>
<td>11.7</td>
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<td>16%</td>
<td>10.6</td>
<td>10.0</td>
<td>6.4</td>
<td>1.8</td>
<td>4.0</td>
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<td>1.8</td>
<td>4.0</td>
<td>8.0</td>
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</table>

Wood Beam Design - Glulam

- calculate $S_{\text{required}}$
- choose width and height so that $bh^2/6 > S_{\text{req'd}}$
- evaluate $V$, $\Delta$, $T$
- consider bracing, connections

**Technical Information**

<table>
<thead>
<tr>
<th>STANDARD SIZES OF STRAIGHT GLULAM MEMBERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Width (mm)</td>
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<tr>
<td>-----------------</td>
</tr>
<tr>
<td>50</td>
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<td>75</td>
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<td>350</td>
</tr>
<tr>
<td>400</td>
</tr>
<tr>
<td>450</td>
</tr>
</tbody>
</table>

Wood Columns

- slenderness ratio = $L/d_{\text{min}} = L/d_1$
  - $d_1 = \text{smaller dimension}$
  - $l_e/d \leq 50$ (max)

$$f_c = \frac{P}{A} \leq F'_c$$

- where $F'_c$ is the allowable compressive strength parallel to the grain
**Allowable Wood Stress**

\[ F'_c = F_c \left( C_D \right) \left( C_M \right) \left( C_t \right) \left( C_F \right) \left( C_p \right) \]

- where:
  - \( F_c = \) compressive strength parallel to grain
  - \( C_D = \) load duration factor
  - \( C_M = \) wet service factor \((1.0 \text{ dry})\)
  - \( C_t = \) temperature factor
  - \( C_F = \) size factor
  - \( C_p = \) column stability factor

**Strength Factors**

- wood properties and load duration, \( C_D \)
  - short duration
    - higher loads
    - normal duration
      - \( > 10 \) years
  - stability, \( C_p \)
    - combination curve - tables
    \[ F'_c = F_c^* C_p = \left( F_c C_D \right) C_p \]

**C\(_p\) Charts**

<table>
<thead>
<tr>
<th>( \frac{I_e}{d} )</th>
<th>Sawed</th>
<th>Glu-Lam</th>
<th>( \frac{I_e}{d} )</th>
<th>Sawed</th>
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<td>0.19</td>
<td>0.59</td>
<td>0.494</td>
<td>0.530</td>
</tr>
</tbody>
</table>

**Procedure**

1. obtain \( F'_c \)
   - find \( \frac{l_e}{d} \) or assume \( \frac{l_e}{d} \leq 50 \)
   - compute \( F_{cE} = K_{cE} E \left( \frac{l_e}{d} \right)^2 \)
     - \( K_{cE} = 0.3 \) sawn
     - \( K_{cE} = 0.418 \) glu-lam
   - compute \( F_{c*} \approx F_c C_D \)
   - find \( F_{cE}/F_{c*} \) and get \( C_p \)
   \[ F'_c = F_{c*} C_p \]
Procedure
2. select a section
   – if P & A known, set stress at limit
     • solve for $l_e$, L, or $d_{min}$
   – if P & $l_e$ known,
     • find A, or $d_{min}$
3. continue from 2 until $F'_c$ satisfied

Eccentric Loading Stress Limit
– in reality, as the column flexes, the moment increases
– $P-\Delta$ effect

\[
\frac{f_a}{F_a} + \frac{f_h \times (\text{Magnification factor})}{F_{bx}} \leq 1.0
\]

Column with Bending Design
• interaction equation

\[
\left(\frac{f_c}{F'_c}\right)^2 + \frac{f_{bx}}{F'_{bx}} \left[\frac{1 - f_c}{F_{cEx}}\right] \leq 1.0
\]

() term – magnification factor for $P-\Delta$
$F'_{bx}$ – allowable bending strength

Structural Supervision
• review changes in shop drawings!
• inspection of construction
  – verify compliance with plans
• some materials require more
  – variability of materials
  – sampling and testing
Construction Requirements - Wood

• if not treated
  – height above exposed ground
    • 18” joists, 12” girders
  – in masonry or concrete
    • provide ½” air space
• foundation sills must be treated
• structural members
  – must be protected from exposure to weather and water

Construction Requirements - Wood

• crawl space ventilation
• fire stops
  – walls
    • at ceiling and floor and every 10’ along
  – interconnections
    • soffits and dropped ceilings
  – concealed spaces
    • access for passage of fire
    • stairways & between floors and roof