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

- moisture
  - exchanges with air easily
  - excessive drying causes warping and shrinkage
  - strength varies some

Wood Properties

- load duration
  - short duration
    - higher loads
  - normal duration
    - > 10 years

Wood Properties

- creep
  - additional deformation with no additional load
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 visual
  - standard mechanical
  - 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

Engineered Wood

- 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)
- wood fibers
  - Hardieboard: cement & wood

Timber Elements

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

Timber Elements

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

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

Approximate Depths

- beams
  - joists
  - girders
  - lateral bracing

- deflection
  - elastic
  - creep
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:

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

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

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

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
  - \( C_{fu} \): flat use factor
    - not decking
  - \( C_i \): incising factor
    - increase depth for pressure treatment
  - \( C_t \): temperature factor
    - lose strength at high temperatures
Adjustment Factors

- **terms**
  - $C_r = \text{repetitive member factor}$
    - 1.15 for more than 3 joists, < 24" o.c., or connected by load-distributing element
  - $C_H = \text{shear stress factor}$
    - splitting
  - $C_v = \text{volume factor for glulam}$
    - replaces $C_F$ for timber
  - $C_L = \text{beam stability factor}$
    - beams without full lateral support

Load Combinations

- **design loads, take the bigger of**
  - $(\text{dead loads})/0.9$
  - $(\text{dead loads} + \text{any possible combination of live loads})/C_D$

- **deflection limits**
  - no load factors
  - for stiffer members:
    - $\Delta_T\text{ max from } LL + 0.5(DL)$
    - 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>
</tr>
</thead>
<tbody>
<tr>
<td>Roof beams:</td>
<td></td>
<td></td>
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<tr>
<td>Industrial</td>
<td>L/180</td>
<td>L/120</td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>plaster ceiling</td>
<td>L/240</td>
<td>L/180</td>
</tr>
<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>Moisture content</th>
<th>Bonding parallel $F_b$</th>
<th>Compression parallel $F_c$</th>
<th>Tension parallel $F_t$</th>
<th>Shear in beam $F_s$</th>
<th>Compression perpendicular $F_p$</th>
<th>Modular elasticity $E$ (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16%</td>
<td>13.0</td>
<td>12.5</td>
<td>6.3</td>
<td>1.9</td>
<td>4.3</td>
<td>12.0</td>
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<tr>
<td>16%</td>
<td>12.1</td>
<td>11.7</td>
<td>7.3</td>
<td>1.8</td>
<td>4.0</td>
<td>11.0</td>
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<tr>
<td>16%</td>
<td>10.6</td>
<td>10.9</td>
<td>6.4</td>
<td>1.8</td>
<td>4.0</td>
<td>9.0</td>
</tr>
<tr>
<td>16%</td>
<td>8.2</td>
<td>10.0</td>
<td>4.9</td>
<td>1.8</td>
<td>4.0</td>
<td>9.0</td>
</tr>
</tbody>
</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>
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</thead>
<tbody>
<tr>
<td>Beam Width (mm)</td>
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<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Nominal Dimension</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>75</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>125</td>
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<td>225</td>
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<tr>
<td>250</td>
</tr>
<tr>
<td>300</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>

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**Wood Columns**

- slenderness ratio $= L/d_{\text{min}} = L/d_1$
  - $d_1 = \text{smaller dimension}$
  - $\ell/e \leq 50$ (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:
  - $F_c = \text{compressive strength parallel to grain}$
  - $C_D = \text{load duration factor}$
  - $C_M = \text{wet service factor (1.0 dry)}$
  - $C_t = \text{temperature factor}$
  - $C_F = \text{size factor}$
  - $C_p = \text{column stability factor}$

---

**Strength Factors**

- wood properties and load duration, $C_D$
  - short duration
    - higher loads
  - normal duration
    - $> 10$ years

- stability, $C_p$
  - combination curve - tables

$$F'_c = F_c C_p = (F_c C_D) C_p$$
**C_p Charts**

**Procedure**

1. obtain $F'_{c}$
   - find $l_e/d$ or assume $(l_e/d \leq 50)$
   - compute $F_c' = \frac{K_{cE}E}{(l_e/d)^2}$
     - $K_{cE} = 0.3$ sawn
     - $K_{cE} = 0.418$ glu-lam
   - compute $F_c^* \approx F_c C_D$
   - find $F_c/E/F_c^*$ and get $C_p$

   $F_c' = F_c^* C_p$

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
### Column with Bending Design
- **interaction equation**

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

\(f_c\) 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

- **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