Wood Construction

Wood Construction 1
Lecture 19
Applied Architectural Structures
ARCH 631
DR. ANNE NICHOLS
FALL 2013

Timber Construction

• studs, beams
• floor diaphragms & shear walls

Wood Construction 2
Lecture 18
Architectural Structures III
ARCH 631

Timber Construction

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

Wood Construction 3
Lecture 18
Architectural Structures III
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Timber Construction

• glulam arches & frames
  – manufactured or custom shapes
  – glue laminated
  – bigger members

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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
- temperature
  - steam
  - volatile products
  - combustion

Wood Properties

- load duration
  - short duration
    - higher loads
  - normal duration
    - > 10 years
- 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 mechanical
  – economy mechanical

• 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

Timber Elements

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

Allowable Stresses

- **design values**
  - \( F_b \): bending stress
  - \( F_t \): tensile stress
  - \( F_v \): horizontal shear stress
  - \( F_c \): compression stress (perpendicular to grain)
  - \( F_{cL} \): 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
    \[ C_F = \left( \frac{12}{d} \right)^{0.6} \leq 1.0 \]
  - \( C_F \): size factor
    - visually graded sawn lumber and round timber > 12” depth
    \[ C_F = \left( \frac{12}{d} \right)^{0.6} \leq 1.0 \]
  - \( C_{fu} \): 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**
  - $C_r$ = repetitive member factor
    - 1.15 for more than 3 joists, < 24" o.c., or connected by load-distributing element
  - $C_H$ = shear stress factor
    - splitting
  - $C_v$ = volume factor for glulam
    - replaces $C_F$ for timber
  - $C_L$ = beam stability factor
    - beams without full lateral support

**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>
<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>
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**Wood Beam Design - Glulam**

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

<table>
<thead>
<tr>
<th>Timberbeam Glulam</th>
<th>Moisture content</th>
<th>Bending parallel Fb</th>
<th>Compression parallel Fc</th>
<th>Tension parallel Fc</th>
<th>Shear in Beam Fb</th>
<th>Compression perpendicular Fp</th>
<th>Modulus of elasticity E(GPa)</th>
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<tbody>
<tr>
<td>E11</td>
<td>16%</td>
<td>12.8</td>
<td>12.5</td>
<td>8.3</td>
<td>1.9</td>
<td>4.3</td>
<td>12.0</td>
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<tr>
<td>Engineering</td>
<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>No.1 Framing</td>
<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>
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<tr>
<td>No.2 Framing</td>
<td>16%</td>
<td>8.2</td>
<td>10.0</td>
<td>4.9</td>
<td>1.8</td>
<td>4.0</td>
<td>8.0</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**

**STANDARD SIZES OF STRAIGHT GLULAM MEMBERS**

<table>
<thead>
<tr>
<th>Beam Width (mm)</th>
<th>Beam Depth (mm)</th>
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<tbody>
<tr>
<td>Nominal Diameter</td>
<td>Premium Finish</td>
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<tr>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>65</td>
<td>30</td>
</tr>
<tr>
<td>85</td>
<td>30</td>
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<td>100</td>
<td>30</td>
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<td>125</td>
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<td>150</td>
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<td>175</td>
<td>30</td>
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<tr>
<td>300</td>
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<tr>
<td>325</td>
<td>30</td>
</tr>
<tr>
<td>350</td>
<td>30</td>
</tr>
</tbody>
</table>

**Allowable Wood Stress**

$F_c' = F_c (C_D) (C_M) (C_t) (C_F) (C_p)$

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

**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

**Strength Factors**

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

- stability, $C_p$
  - combination curve - tables
  
  $$F_c' = F_c^* C_p = \left( F_c C_D \right) C_p$$
Procedure

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

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

\[
\frac{f_a}{F_a} + \frac{f_b \times (Magnification \ factor)}{F_{bx}} \leq 1.0
\]
Column with Bending Design

- interaction equation

\[
\frac{f_c}{F_c'} + \frac{f_{bx}}{F_{bx}^{cEx}} \leq 1.0
\]

() term – magnification factor for P-\(\Delta\)

\(F_{bx}^{cEx}\) – 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