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 1
Lecture 19
Applied Architectural Structures
ARCH 631
F2008abn

Wood Construction 2
Lecture 18
Architectural Structures III
ARCH 631
F2007abn

Wood Construction 3
Lecture 18
Architectural Structures III
ARCH 631
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Wood Construction 4
Lecture 18
Architectural Structures III
ARCH 631
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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
  - 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)
  - laminated veneered lumber (LVL)
- **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

**Timber Elements**

- beams
  - joists
  - girders
  - lateral bracing
  - deflection
    - elastic
    - creep

**Approximate Depths**

- Detailed diagrams and tables showing approximate depths for various timber elements.
**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
  - $(\text{dead loads})/0.9$
  - $(\text{dead loads} + \text{any possible combination of live loads})/C_D$

- 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>
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<td>Roof beams:</td>
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<td>L/120</td>
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<tr>
<td>plaster ceiling</td>
<td>L/240</td>
<td>L/180</td>
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<td>no plaster</td>
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<td>L/240</td>
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<tr>
<td>Floor beams:</td>
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<tr>
<td>Ordinary Usage</td>
<td>L/360</td>
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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

Wood Columns

- slenderness ratio = $L/d_{\text{min}} = L/d_1$
- $d_1 =$ 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 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
    \[ F'_c = F_c^* C_p = \left( F_c C_D \right) C_p \]

Procedure

1. obtain \( F'_c \)
   - find \( l_e/d \) or assume \( l_e/d \leq 50 \)
   - compute \( F_{cE} = \frac{K_{cE} E}{\left( l_e/d \right)^2} \)
     - \( K_{cE} = 0.3 \) 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 $\ell$, $L$, or $d_{\min}$
   - if $P$ & $\ell$ known,
     - find $A$, or $d_{\min}$

3. continue from 2 until $F_c'$ satisfied

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**Eccentric Loading Stress Limit**

- in reality, as the column flexes, the moment increases

- $P$-$\Delta$ effect

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

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**Column with Bending Design**

- interaction equation

\[
\left[ \frac{f_c'}{F_c'} \right]^2 + \frac{f_{bx}}{F_{bx}' \left[ 1 - \frac{f_c'}{F_{cEx}} \right]} \leq 1.0
\]

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

$F'_{bx}$ – allowable bending strength

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**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

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**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