wood construction: column design
Compression Members (revisited)

- designed for strength & stresses
- designed for serviceability & deflection
- need to design for stability
  - ability to support a specified load without sudden or unacceptable deformations
Effect of Length (revisited)

- **long & slender**
- **short & stubby**
Critical Stresses (revisited)

• when a column gets stubby, crushing will limit the load
• real world has loads with eccentricity
**Bracing (revisited)**

- **bracing affects shape of buckle in one direction**
- **both should be checked!**
Wood Columns

- slenderness ratio = $L/d_{\min}$
  - $d_1 =$ smallest 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
  - bracing common
  - posts, round, built-up
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

(Fig. 9.23)
Strength Factors

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

• stability, $C_p$
  – combination curve - tables

$$F' = F^* C_p = (F_c C_D) C_p$$

http://www.swst.org/teach/set2/struct1.html
### $C_p$ Charts – Chapter 9, pg 478

#### Table 9.3 Column Stability Factor $C_p$

<table>
<thead>
<tr>
<th>$F_{CE}/F_{C*}$</th>
<th>Sawed</th>
<th>Glu-Lam</th>
<th>$F_{CE}$/Sawed</th>
<th>$F_{CE}$/Glu-Lam</th>
<th>$F_{CE}$/Sawed</th>
<th>$F_{CE}$/Glu-Lam</th>
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\[
F_{CE} = \frac{0.822 E_{min}'}{\left(\frac{d}{l}\right)^2} (c = 0.8 \text{ sawn}, c = 0.9 \text{ glulam})
\]
Table 12  Allowable Column Loads—Selected Species/Sizes. (Continued)

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<th>Eff.</th>
<th>l/d</th>
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<th>Fc/Fc'</th>
<th>Cp</th>
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<th>Pa (k)</th>
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<td>Fc = 1500</td>
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</table>

Wood Columns 10  Architectural Structures  Su2018abn
Lecture 13  ARCH 331
Procedure for Analysis

1. calculate $L_e/d_{\text{min}}$
   - $KL/d$ each axis, choose largest

2. obtain $F'_c$
   - compute
     $$F_{cE} = \frac{0.822E'_\text{min}}{(l_e/d)^2} = \left(\frac{K_{CE}E}{(l_e/d)^2}\right)$$
     
     - $(K_{CE} = 0.3 \text{ sawn})$
     - $(K_{CE} = 0.418 \text{ glu-lam})$

     - $E'_\text{min} = E_{\text{min}}(C_M)(C_t)(C_T)(C_i)$

3. compute $F'_c \approx F_c C_D$

4. calculate $F_{cE}/F'_c$ and get $C_p$ (Table 9.3)

5. calculate $F'_c = F'_c C_p$
Procedure for Analysis (cont’d)

6. **compute** \( P_{\text{allowable}} = F'_c \cdot A \)
   - or find \( f_{\text{actual}} = \frac{P}{A} \)

7. **is** \( P \leq P_{\text{allowable}} \) ? (or \( f_{\text{actual}} \leq F'_c \) ?)
   - yes: OK
   - no: overstressed & no good
Procedure for Design

1. guess a size (pick a section)

2. calculate $L_e/d_{\text{min}}$
   - $KL/d$ each axis, choose largest

3. obtain $F'_c$
   - compute
     $$F_{cE} = \frac{0.822E'_\text{min}}{(l_e/d)^2} = \frac{K_{cE}E}{(l_e/d)^2}$$
     - $K_{cE} = 0.3$ sawn
     - $K_{cE} = 0.418$ glu-lam
     - $E'_\text{min} = E_\text{min}(C_M)(C_t)(C_T)(C_i)$

4. compute $F'_c \approx F_cC_D$

5. calculate $F_{cE}/F'_c$ and get $C_p$ (Table 9.3)
Procedure for Design (cont’d)

6. compute \( F'_c = F^*_c C_p \)
7. compute \( P_{\text{allowable}} = F'_c \cdot A \)
   • or find \( f_{\text{actual}} = P/A \)
8. is \( P \leq P_{\text{allowable}} \)? (or \( f_{\text{actual}} \leq F'_c \)?)
   • yes: OK
   • no: pick a bigger section and go back to step 2.
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
Design of Columns with Bending

- satisfy
  - strength
  - stability
- pick
  - section

(a) Framed beam (shear) connection.
\( e = \text{Eccentricity}; \ M = P \times e \)

(b) Moment connection (rigid frame).
\( M = \text{Moment due to beam bending} \)

(c) Timber beam–column connection.
\( e = \frac{d}{2} = \text{Eccentricity}; \ M = P \times e \)

(d) Upper chord of a truss—compression plus bending.
\( M = \frac{\omega l^2}{8} \)
Design

• Wood

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

[ ] term – magnification factor for P-Δ

\( F'_{bx} \) – allowable bending strength
Design Steps Knowing Loads

1. assume limiting stress
   • buckling, axial stress, combined stress
2. solve for r, A or S
3. pick trial section
4. analyze stresses
5. section ok?
6. stop when section is ok
Laminated Timber Arches

- two & three hinged arches
- bent to wide range of curves
- bending and compression
- residual stress from laminating, $C_c$
Laminated Arch Design

- radius of curvature, $R$, limited by lam thickness, $t$
  - $R = 100t$ – southern pine & hardwoods
  - $R = 125t$ – softwood
- $r = \text{radius to inside face of laminations}$
- $C_C = 1 - 2000 \left( \frac{t}{r} \right)^2$
- $F'_b = F_b(C_F C_C)$