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 = $L/d_{\text{min}}$
  - $d_1$ = 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

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

- 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

\[
F'_c = F_c^* C_p = \left( F_c C_D \right) C_p
\]
### Column Stability Factor \( C_p \)

**Table 14** Column Stability Factor \( C_p \)

\[
F_{CE} = \frac{0.822E'}{(\%a)^2} \quad (c = 0.8 \text{sawn, } c = 0.9 \text{ glulam})
\]

\[
F_c' = C_p \cdot F_c^*\quad F_{CE} = \frac{30E}{(l/d)^2} \text{ for sawed posts} \quad F_{CE} = \frac{418E}{(l/d)^2} \text{ for glu-lam posts}
\]

<table>
<thead>
<tr>
<th>( F_{CE} )</th>
<th>Sawed</th>
<th>Glu-Lam</th>
</tr>
</thead>
<tbody>
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<td>0.00</td>
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<td>0.000</td>
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### Column Charts – Not in Appendix

**Table 12  Allowable Column Loads—Selected Species/Sizes. (Continued)**

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<th>Eff. Col.</th>
<th>l/d</th>
<th>(l/d) sq</th>
<th>Fce</th>
<th>FcepFc'</th>
<th>Cp</th>
<th>Fc(ksi)</th>
<th>Pk</th>
<th>A = 56.25</th>
<th>A = 71.25</th>
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<td>.1728</td>
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<td>199</td>
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</tr>
</tbody>
</table>

**DF-L No. 1** (P&T)  
**DF-L No. 1 & Btr Dim.Lum**  
Fc = 1000  
Ec = 1500  
E = 1.6  
E = 1.8
Procedure for Analysis

1. calculate \( \frac{L_e}{d_{min}} \)
   - \( KL/d \) each axis, choose largest

2. obtain \( F'_{c} \)
   - compute
     \[
     F_{cE} = \frac{0.822 E_{min}'}{\left(\frac{l_e}{d}\right)^2} = \frac{K_{cE} E}{\left(\frac{l_e}{d}\right)^2}
     \]
     - \( K_{cE} = 0.3 \) sawn
     - \( K_{cE} = 0.418 \) glu-lam
     - \( E_{min}' = E_{min} (C_M)(C_t)(C_T)(C_i) \)

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 \( f_{\text{actual}} = P/A \)

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** $L_e/d_{min}$
   - $KL/d$ each axis, choose largest

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

4. **compute** $F'_c \approx F_c C_D$

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
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-\(\Delta\)

\(F'_{bx}\) – 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
- \( r = \) radius to inside face of laminations
- \( C_c = 1 - 2000 \left( \frac{t}{r} \right)^2 \)
- \( F_b' = F_b (C_F C_c) \)