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

\[ \frac{L}{d} = \text{large number} \quad \text{Buckling} \]

\[ \frac{L}{d} = \text{small number} \quad \text{Crushing} \]
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

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

- 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 (Table 10.3)
Strength Factors

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

• stability, $C_p$
  – combination curve - tables

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

http://www.swst.org/teach/set2/struct1.html
### $C_p$ Charts – Appendix A

#### Table 14: Column Stability Factor $C_p$

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<th>$F_{CE}$</th>
<th>Sawed $C_p$</th>
<th>Glu-Lam $C_p$</th>
<th>$F_{CE}$</th>
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<th>Glu-Lam $C_p$</th>
<th>$F_{CE}$</th>
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# Column Charts – Appendix A, 12 & 13

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**Notes:**
- Fc = 1000, E = 1.6
- Fc = 1500, E = 1.8
Procedure for Analysis

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

2. obtain \( F'_c \)
   - compute \( F_{cE} = \frac{K_{cE} E}{\left(\frac{L_e}{d}\right)^2} \)
     - \( K_{cE} = 0.3 \) sawn
     - \( K_{cE} = 0.418 \) glu-lam

3. compute \( F_c^* \approx F_c C_D \)

4. calculate \( F_{cE}/F_c^* \) and get \( C_p \) (Table 14)

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 $F_{cE} = \frac{K_{cE}E}{(L_e/d)^2}$
     - $K_{cE} = 0.3$ sawn
     - $K_{cE} = 0.418$ glu-lam

4. compute $F_c^* \approx F_c C_D$

5. calculate $F_{cE}/F_c^*$ and get $C_p$ (Table 14)
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
- $r = \text{radius to inside face of laminations}$
- $C_c = 1 - 2000 \left( \frac{t}{r} \right)^2$
- $F_b' = F_b (C_F C_c)$