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**

![Diagram of long & slender column with buckling and critical load]

![Diagram of short & stubby column with crushing and critical load]
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:
  \[ F_{c} = \text{compressive strength parallel to grain} \]
  \[ C_{D} = \text{load duration factor} \]
  \[ C_{M} = \text{wet service factor} \]
  \[ C_{M} = 1.0 \text{ dry} \]
  \[ C_{t} = \text{temperature factor} \]
  \[ C_{F} = \text{size factor} \]
  \[ C_{p} = \text{column stability factor} \]

(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

\[
F'_c = F_c^* C_p = \left( F_c C_D \right) C_p
\]
### $C_p$ Charts – Appendix A

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

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<tr>
<th>$F_{CE}$</th>
<th>Sawed</th>
<th>Glu-Lam</th>
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<tbody>
<tr>
<td>$F_{c}^*$</td>
<td>$C_p$</td>
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**Notes:**
- $F_{CE} = \frac{30E}{(l/d)^2}$ for sawed posts
- $F_{CE} = \frac{418E}{(l/d)^2}$ for glu-lam posts
## Column Charts – Appendix A, 12 & 13

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

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<th>Eff.</th>
<th>l/d</th>
<th>(l/d) sq</th>
<th>Fce</th>
<th>Fce/Fc</th>
<th>Cp</th>
<th>Fc (psi)</th>
<th>Pa (k)</th>
<th>Pa (k)</th>
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Procedure for Analysis

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

2. 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

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

4. compute $F_c^* \approx F_cC_D$

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 $P_{allowable} = F'_c A$
   - or find $f_{actual} = P/A$

8. is $P \leq P_{allowable}$? (or $f_{actual} \leq F'_c$?)
   - 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-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

- $r =$ radius to inside face of laminations

- $C_C = 1 - 2000\left(\frac{t}{r}\right)^2$

- $F'_{b'} = F_b(C_FC_C)$