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

Critical Stresses (revisited)

- when a column gets stubby, crushing will limit the load
- real world has loads with eccentricity

Effect of Length (revisited)

- long & slender
- short & stubby
**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
  - $I/e/d \leq 50$ (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
  
  $$F'_c = F_c C'_p = \left(F_c C_D\right)C_p$$

[Image of wood columns with diagrams and calculations]
Procedure for Analysis

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

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

3. compute $F_{c'} \approx F_cC_D$

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 $P_{\text{allowable}} = F'_{c}A$
   - 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 \( L_e/d_{\text{min}} \)
   - KL/d each axis, choose largest
3. obtain \( F_c' \)
   - compute \( F_{cE} = \frac{0.822 E'_\text{min}}{(l_e/d)^2} = \frac{K_{cE}E}{(l_e/d)^2} \)
   - \( K_{cE} = 0.3 \) sawn
   - \( K_{cE} = 0.418 \) glu-lam
   - \( E'_\text{min} = E_{\text{min}}(C_M)(C_i)(C_T)(C_i) \)
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-Δ

\( F_{bx}' \) – allowable bending strength

Laminated Timber Arches

- two & three hinged arches
- bent to wide range of curves
- bending and compression
- residual stress from laminating, \( C_c \)

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 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
- \( C_c = 1 - 2000 \left( \frac{t}{r} \right)^2 \)
- \( F_b' = F_b (C_F C_o) \)