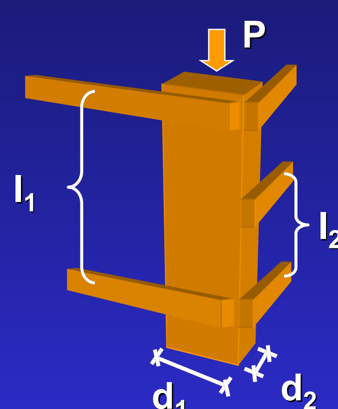
Compression Member Design

- Column Types:
  - Simple Solid Wood Columns
  - Spaced Columns, Connector Joined
  - Built-up Columns
- Use net section if net section occurs in critical buckling region
- Use gross section if net section does not occur in critical buckling region

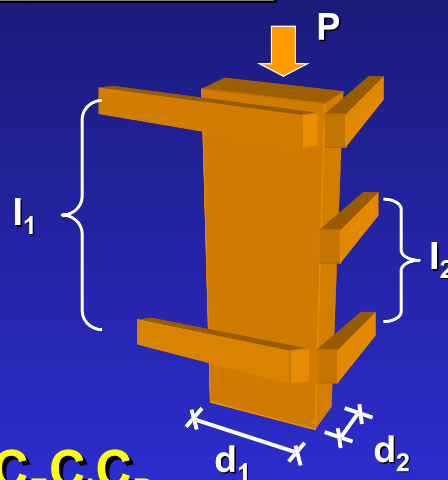
Compression Member Design

- Column Failure Modes:
  - Short Columns (small l/d ratios) – fail by crushing
  - Intermediate Columns – fail by combination of crushing and buckling
  - Long Columns (high l/d ratios) – behave as Euler columns and fail by lateral buckling



- <u>Compression design equations:</u>

$$f_c = \frac{P}{d_1 d_2} \le F_c'$$

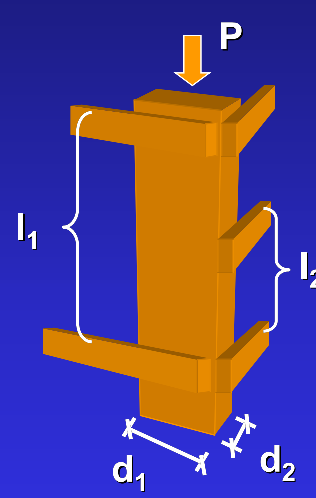


$$F_c' = F_c C_D C_M C_t C_F C_i C_P$$

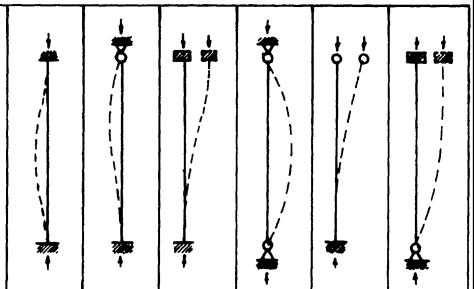
- <u>Column stability factor</u>, C_P:
  - when column is fully supported to prevent lateral displacement, $C_P = 1$
  - find unsupported length, l_1 and l_2
  - then find effective length, l_e, from Appendix G

$$l_e = (K_e)(l)$$

  - find maximum slenderness ratio from l_{e1}/d_1 or l_{e2}/d_2



Buckling Length Coefficients, K_e



Buckling modes						
Theoretical K_e value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design K_e when ideal conditions approximated	0.65	0.80	1.2	1.0	2.10	2.4

End condition code	
	Rotation fixed, translation fixed
	Rotation free, translation fixed
	Rotation fixed, translation free
	Rotation free, translation free

Found in Appendix G of NDS (p. 156)

- <u>Column stability factor</u>, C_P:
  - calculate slenderness ratio
  - $l_e/d < 50$ permanently or $l_e/d < 75$ during construction
  - calculate C_P by:

$$C_P = \frac{1+\left(\frac{F_{cE}}{F_c^*}\right)}{2c} - \sqrt{\left[\frac{1+\left(\frac{F_{cE}}{F_c^*}\right)}{2c}\right]^2 - \frac{\left(\frac{F_{cE}}{F_c^*}\right)}{c}}$$

- <u>Column stability factor</u>, C_P:

$$C_P = \frac{1+\left(\frac{F_{cE}}{F_c^*}\right)}{2c} - \sqrt{\left[\frac{1+\left(\frac{F_{cE}}{F_c^*}\right)}{2c}\right]^2 - \frac{\left(\frac{F_{cE}}{F_c^*}\right)}{c}}$$

  - F_c^* is tabulated compression parallel-to-grain design value multiplied by all adjustments except C_P

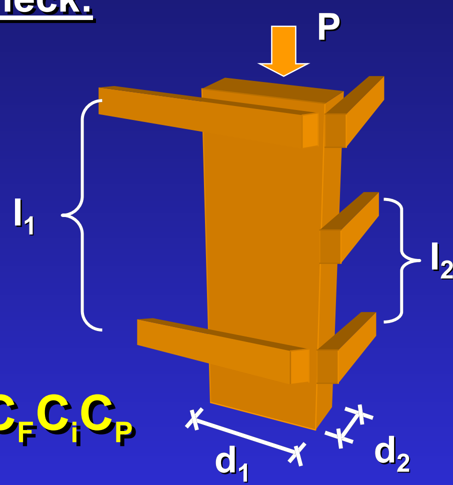
$$F_{cE} = \frac{K_{cE}E'}{\left(\frac{l_e}{d}\right)^2}$$

	K_{cE}	c
Visually graded lumber	0.3	0.8
MEL	0.384	0.85
MSR	0.418	0.9

- **Compression check:**

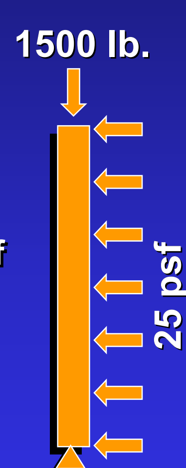
$$f_c = \frac{P}{d_1 d_2} \le F_c'$$

$$F_c' = F_c C_D C_M C_t C_F C_i C_P$$



Beam-Column Design Example

- **Given:**
  - 10-ft-long Wall Studs
  - No. 1 Douglas fir - Larch 2x4 spaced 16 in. OC
  - Axial loads of 1000 lb. Snow and 500 lb. Dead; side loads of 25 psf from Wind.
  - Wall sheathing provides lateral support for width (1.5 in. dimension)



- **Find:**
  - Is beam-column sized properly?

- **Assume:**
  - Dry conditions
  - Normal temperatures
  - Full lateral support for width of stud (1.5 in. dimension)
  - Column is pinned at each end

Solution:

- Check load combinations from Standard Building Code
  - for bending: D + W
  - for compression: D + S
  - for combined bending and compression:
    - D + S + 1/2W

Design Data: No. 1 Douglas fir Larch 2x4

A = 5.25 in^2	F_b = 1000 psi
Sxx = 3.063 in^3	F_c = 1500 psi
Ixx = 5.359 in^4	E = 1.7 x 10^6 psi

Design Data: No. 1 Douglas fir Larch 2x4

C_D = 1.15 for snow load, 1.6 for wind load

C_M = 1.0

C_t = 1.0

C_L = 1.0 (full lateral support by wall sheathing)

C_P = ? (to be determined)

C_F = 1.5 for F_b

C_F = 1.15 for F_c

C_r = 1.15 (16 in. spacing with sheathing)

- **Column Stability Factor**, C_P
  - Effective length for column pinned at each end

$$l_e = Kel = (1.0)(120\ in) = 120\ in$$

  - Slenderness Ratio, l_e/d

$$\frac{l_e}{d} = \frac{120\ \text{in.}}{3.5\ \text{in.}} = 34.3$$

- **Column Stability Factor**, C_P

$$C_P = \frac{1 + \left(\frac{F_{cE}}{F_c^*}\right)}{2c} - \sqrt{\left[\frac{1 + \left(\frac{F_{cE}}{F_c^*}\right)}{2c}\right]^2 - \frac{\left(\frac{F_{cE}}{F_c^*}\right)}{c}}$$

$$F_{cE} = \frac{K_{cE}E'}{\left(\frac{l_e}{d}\right)^2}$$

$$F_c^* = F_c C_D C_M C_t C_F C_i$$

- **Column Stability Factor**, C_P

$$E' = E\, C_M C_t C_i C_T = 1.7\text{x}10^6 \text{ psi}$$

$$F_{cE} = \frac{K_{cE}E'}{\left(\frac{l_e}{d}\right)^2} = \frac{(0.3)(1.7\text{x}10^6 \text{ psi})}{(34.3)^2} = 433 \text{ psi}$$

$$F_c^* = F_c C_D C_F = (1500\,\text{psi})(1.15)(1.15) = 1984\,\text{psi}$$

- **Column Stability Factor, C_P**

$$C_P = \frac{1+\left(\frac{433\ \text{psi}}{1984\ \text{psi}}\right)}{2(0.8)} - \sqrt{\left[\frac{1+\left(\frac{433\ \text{psi}}{1984\ \text{psi}}\right)}{2(0.8)}\right]^2 - \frac{\left(\frac{433\ \text{psi}}{1984\ \text{psi}}\right)}{0.8}}$$

$$C_P = 0.207$$

- **Check Compression Stress:**

$$f_c = \frac{P}{A} \leq F_c'$$

$$f_c = \frac{(1500\ \text{lb.})}{(5.25\ \text{in}^2)}$$

$$f_c = 286\ \text{psi}$$

- **Check Compression Stress:**

$$F_c' = F_c C_D C_P C_F$$

$$F_c' = (1500\ \text{psi})(1.15)(0.207)(1.15)$$

$$F_c' = 411\ \text{psi}$$

$$f_c = 286\ \text{psi} < F_c' = 411\ \text{psi}$$

Conclusion: stud is acceptable in compression stress only, we still need to check combined bending and compression later