

**ARCHITECTURAL STRUCTURES:  
FORM, BEHAVIOR, AND DESIGN**

**ARCH 331**

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**SUMMER 2014**

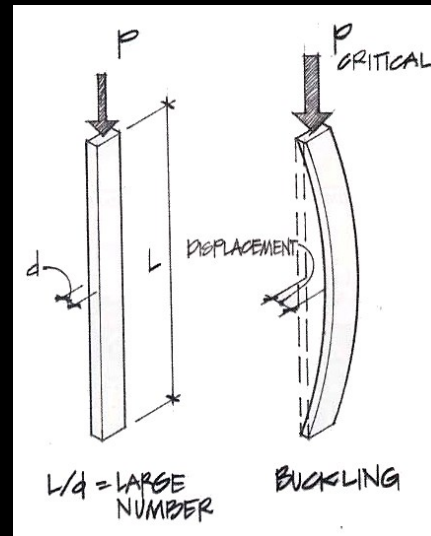
**lecture  
thirteen**

**wood construction:  
column design**



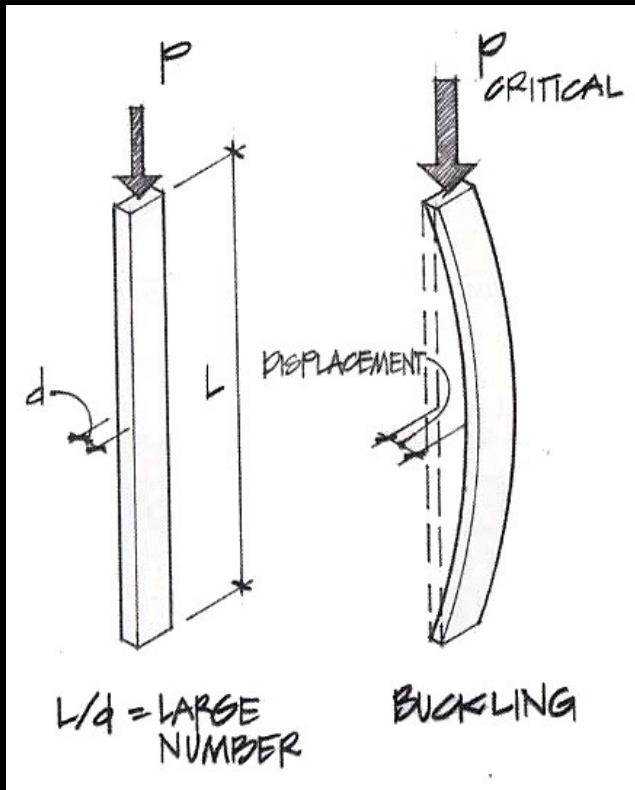
# Compression Members (revisited)

- designed for strength & stresses
- designed for serviceability & deflection
- need to design for stability
  - ability to support a specified load without sudden or unacceptable deformations

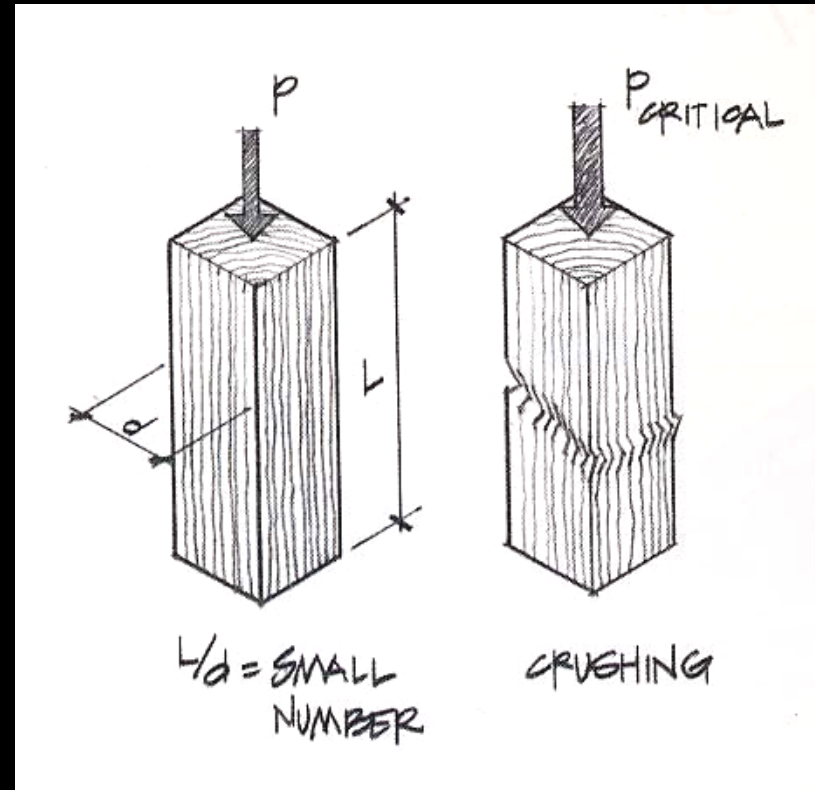


# Effect of Length (revisited)

- long & slender

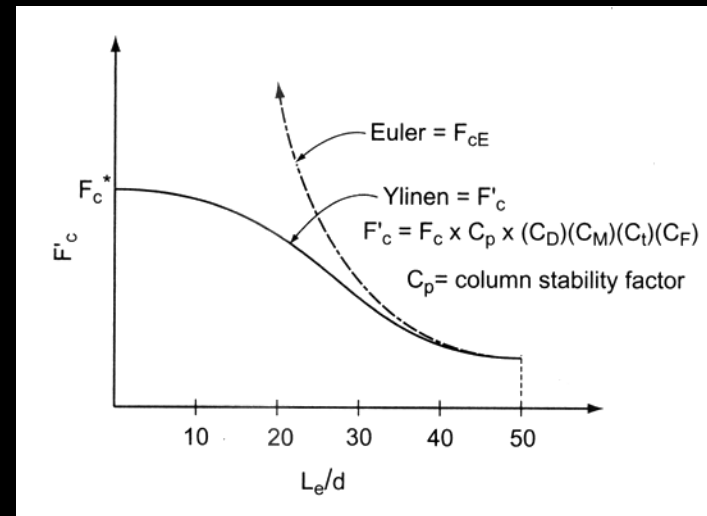


- short & stubby



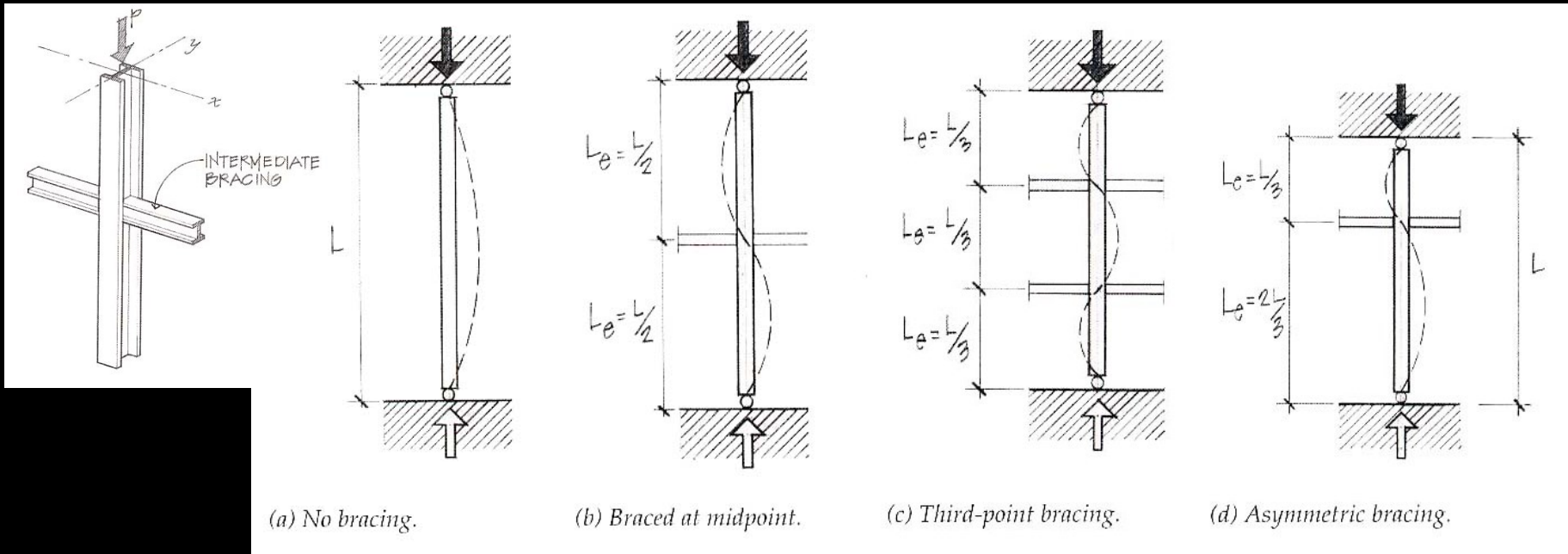
# Critical Stresses (revisited)

- 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!

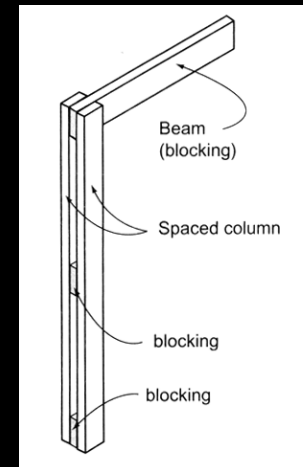
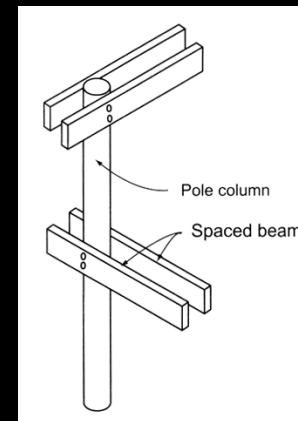
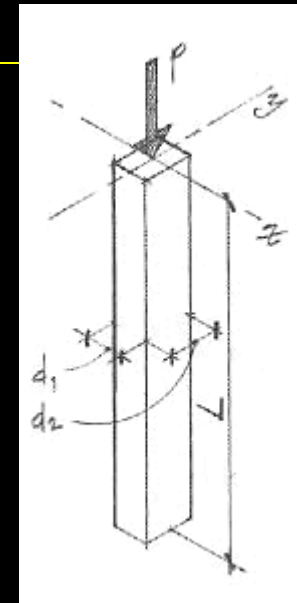


# Wood Columns

- *slenderness ratio* =  $L/d_{min}$ 
  - $d_1$  = 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

$$F'_c = F_c (C_D)(C_M)(C_t)(C_F)(C_p)$$

- where:

$F_c$  = compressive strength parallel to grain

$C_D$  = load duration factor

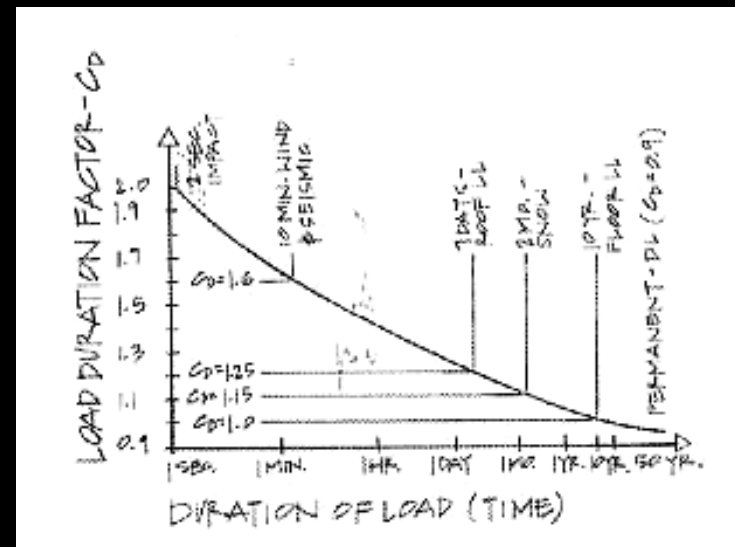
$C_M$  = wet service factor (1.0 dry)

$C_t$  = temperature factor

$C_F$  = size factor

$C_p$  = column stability factor

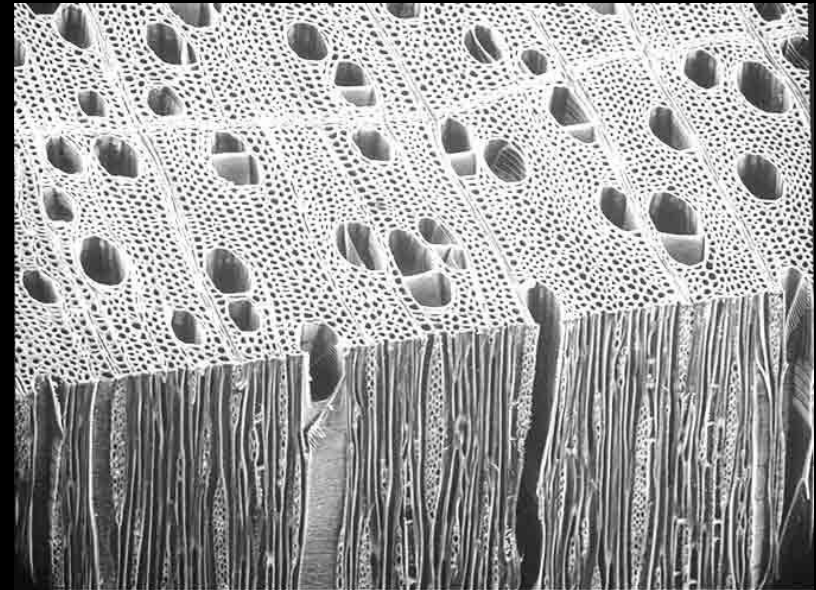
(Table 10.3)





# Strength Factors

- *wood properties and load duration,  $C_D$* 
  - *short duration*
    - *higher loads*
  - *normal duration*
    - *> 10 years*



<http://www.swst.org/teach/set2/struct1.html>

- *stability,  $C_p$* 
  - *combination curve - tables*

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



# $C_p$ Charts – Appendix A

Table 14 Column Stability Factor  $C_p$ .

			$"C_p"$	$F_c' = C_p \cdot F_c^*$ $F_{CE} = \frac{.30 E}{(l/d)^2}$ for sawed posts $F_{CE} = \frac{.418 E}{(l/d)^2}$ for glu-lam posts							
$\frac{F_{CE}}{F_c^*}$	Sawed	Glu-Lam	$\frac{F_{CE}}{F_c^*}$	Sawed	Glu-Lam	$\frac{F_{CE}}{F_c^*}$	Sawed	Glu-Lam	$\frac{F_{CE}}{F_c^*}$	Sawed	Glu-Lam
	$C_p$	$C_p$		$C_p$	$C_p$		$C_p$	$C_p$		$C_p$	
0.00	0.000	0.000	0.40	0.360	0.377	0.80	0.610	0.667	1.20	0.750	0.822
0.01	0.010	0.010	0.41	0.367	0.386	0.81	0.614	0.672	1.22	0.755	0.826
0.02	0.020	0.020	0.42	0.375	0.394	0.82	0.619	0.678	1.24	0.760	0.831
0.03	0.030	0.030	0.43	0.383	0.403	0.83	0.623	0.683	1.26	0.764	0.836
0.04	0.040	0.040	0.44	0.390	0.411	0.84	0.628	0.688	1.28	0.769	0.840
0.05	0.049	0.050	0.45	0.398	0.420	0.85	0.632	0.693	1.30	0.773	0.844
0.06	0.059	0.060	0.46	0.405	0.428	0.86	0.637	0.698	1.32	0.777	0.848
0.07	0.069	0.069	0.47	0.412	0.436	0.87	0.641	0.703	1.34	0.781	0.852
0.08	0.079	0.079	0.48	0.419	0.444	0.88	0.645	0.708	1.36	0.785	0.855
0.09	0.088	0.089	0.49	0.427	0.453	0.89	0.649	0.713	1.38	0.789	0.859
0.10	0.098	0.099	0.50	0.434	0.461	0.90	0.653	0.718	1.40	0.793	0.862
0.11	0.107	0.109	0.51	0.441	0.469	0.91	0.658	0.722	1.42	0.796	0.865
0.12	0.117	0.118	0.52	0.448	0.477	0.92	0.661	0.727	1.44	0.800	0.868
0.13	0.126	0.128	0.53	0.454	0.484	0.93	0.665	0.731	1.46	0.803	0.871
0.14	0.136	0.138	0.54	0.461	0.492	0.94	0.669	0.735	1.48	0.807	0.874
0.15	0.145	0.147	0.55	0.468	0.500	0.95	0.673	0.740	1.50	0.810	0.877
0.16	0.154	0.157	0.56	0.474	0.508	0.96	0.677	0.744	1.52	0.813	0.879
0.17	0.164	0.167	0.57	0.481	0.515	0.97	0.680	0.748	1.54	0.816	0.882
0.18	0.173	0.176	0.58	0.487	0.523	0.98	0.684	0.752	1.56	0.819	0.884
0.19	0.182	0.186	0.59	0.494	0.530	0.99	0.688	0.756	1.58	0.822	0.887

# Column Charts – Appendix A, 12 & 13

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

Eff.										8×8	A = 56.25	8×10	A = 71.25	8×12	A = 86.25
Col.	<i>l/d</i>	<i>(l/d)</i> sq	<i>F<sub>ce</sub></i>	<i>F<sub>ce</sub>/F<sub>c</sub>'</i>		<i>C<sub>p</sub></i>		<i>F<sub>c</sub></i> (psi)		<i>P<sub>a</sub></i> (k)		<i>P<sub>a</sub></i> (k)		<i>P<sub>a</sub></i>	
Len(ft)				Norm	Snow	Norm	Snow	Norm	Snow	Norm	Snow	Norm	Snow	Norm	Snow
12	19.2	368.64	1302.08	1.30	1.13	.7731	.7315	773	841	43.5	47.3	55.1	59.9	66.7	72.6
13	20.8	432.64	1109.47	1.11	0.96	.7258	.6767	726	778	40.8	43.8	51.7	55.4	62.6	67.1
14	22.4	501.76	956.63	0.96	0.83	.6767	.6235	677	717	38.1	40.3	48.2	51.1	58.4	61.8
15	24.00	576.00	833.33	0.83	0.72	.6235	.5694	624	655	35.1	36.8	44.4	46.7	53.8	56.5
16	25.60	655.36	732.42	0.73	0.64	.5747	.5244	575	603	32.3	33.9	40.9	43.0	49.6	52.0
17	27.20	739.84	648.79	0.65	0.56	.5303	.4744	530	546	29.8	30.7	37.8	38.9	45.7	47.1
18	28.80	829.44	578.70	0.58	0.50	.4873	.4336	487	499	27.4	28.0	34.7	35.5	42.0	43.0
19	30.40	924.16	519.39	0.52	0.45	.4475	.3975	448	457	25.2	25.7	31.9	32.6	38.6	39.4
20	32.00	1024.00	468.75	0.47	0.41	.4122	.3673	412	422	23.2	23.8	29.4	30.1	35.6	36.4
21	33.60	1128.96	425.17	0.43	0.37	.3826	.3360	383	386	21.5	21.7	27.3	27.5	33.0	33.3
22	35.20	1239.04	387.40	0.39	0.34	.3518	.3118	352	359	19.8	20.2	25.1	25.5	30.3	30.9
23	36.80	1354.24	354.44	0.35	0.31	.3199	.2869	320	330	18.0	18.6	22.8	23.5	27.6	28.5
24	38.40	1474.56	325.52	0.33	0.28	.3035	.2615	304	301	17.1	16.9	21.6	21.4	26.2	25.9
25	40.00	1600.00	300.00	0.30	0.26	.2785	.2442	279	281	15.7	15.8	19.8	20.0	24.0	24.2
26	41.60	1730.56	277.37	0.28	0.24	.2615	.2267	262	261	14.7	14.7	18.6	18.6	22.6	22.5
27	43.20	1866.24	257.20	0.26	0.22	.2442	.2090	244	240	13.7	13.5	17.4	17.1	21.1	20.7
28	44.80	2007.04	239.16	0.24	0.21	.2267	.2000	227	230	12.8	12.9	16.2	16.4	19.6	19.8
29	46.40	2152.96	222.95	0.22	0.19	.2090	.1819	209	209	11.8	11.8	14.9	14.9	18.0	18.0
30	48.00	2304.00	208.33	0.21	0.18	.2000	.1728	200	199	11.3	11.2	14.3	14.2	17.3	17.1
	DF-L No.1		(P&T)			<i>F<sub>c</sub></i> = 1000		<i>E</i> = 1.6							
	DF-L No.1 & Btr		Dim.Lum			<i>F<sub>c</sub></i> = 1500		<i>E</i> = 1.8							

# Procedure for Analysis

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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)*

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6. *compute  $P_{allowable} = F'_c \cdot A$*

- *or find  $f_{actual} = P/A$*

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

- *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  $F_{cE} = \frac{K_{cE}E}{\left(L_e/d\right)^2}$ 
    - $K_{cE} = 0.3$  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  $P_{allowable} = F'_c \cdot A$ 
  - 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

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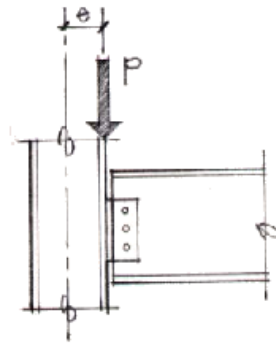
- *light-frame*
  - *light loads*
  - *2x's*
  - *floor joists – 2x6, 2x8, 2x10, 2x12 typical at spacings of 12", 16", 24"*
  - *normal spans of 20-25 ft or 6-7.5 m*
  - *plywood spans between joists*
  - *stud or load-bearing masonry walls*
  - *limited to around 3 stories – fire safety*



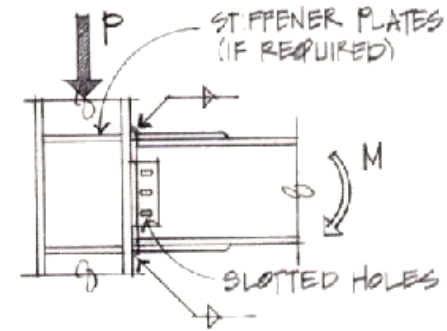


# Design of Columns with Bending

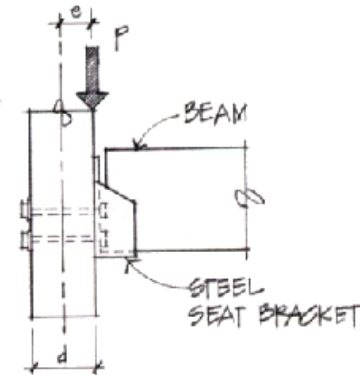
- satisfy
  - strength
  - stability
- pick
  - section



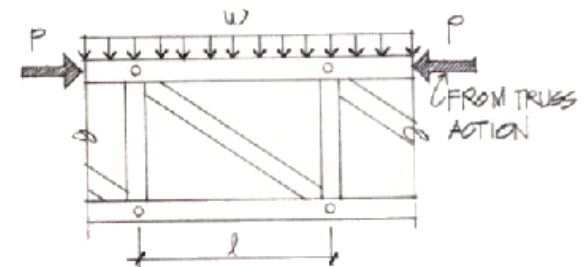
(a) Framed beam (shear) connection.  
 $e = \text{Eccentricity}; M = P \times e$



(b) Moment connection (rigid frame).  
 $M = \text{Moment due to beam bending}$



(c) Timber beam-column connection.  
 $e = d/2 = \text{eccentricity}; M = P \times e$



(d) Upper chord of a truss—compression plus bending.  
 $M = \frac{wl^2}{8}$

# Design

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- Wood

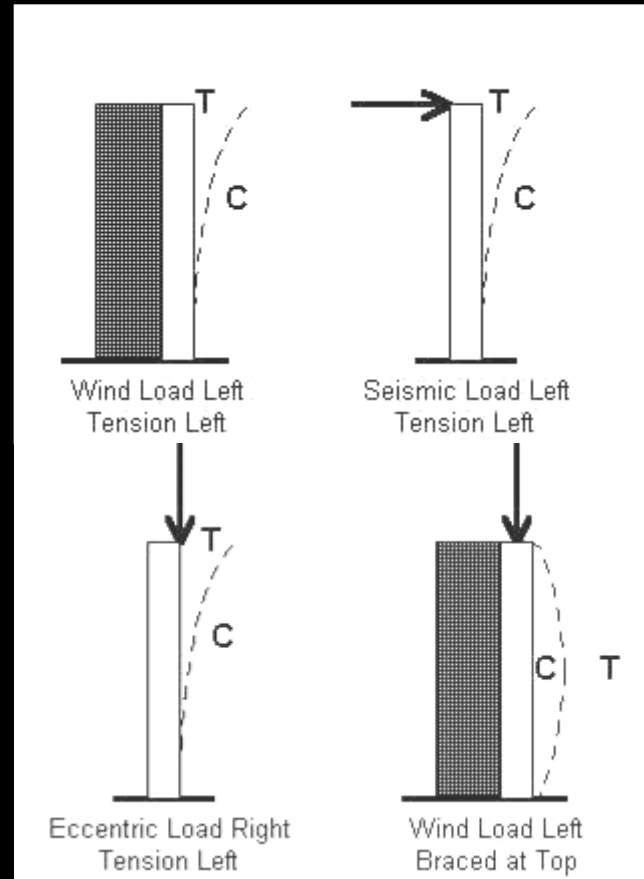
$$\left[ \frac{f_c}{F'_c} \right]^2 + \frac{f_{bx}}{F'_{bx} \left[ 1 - \frac{f_c}{F_{cEx}} \right]} \leq 1.0$$

$\left[ \right]$  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
- $C_C = 1 - 2000 \left( \frac{t}{r} \right)^2$
- $F_b' = F_b (C_F C_C)$

