

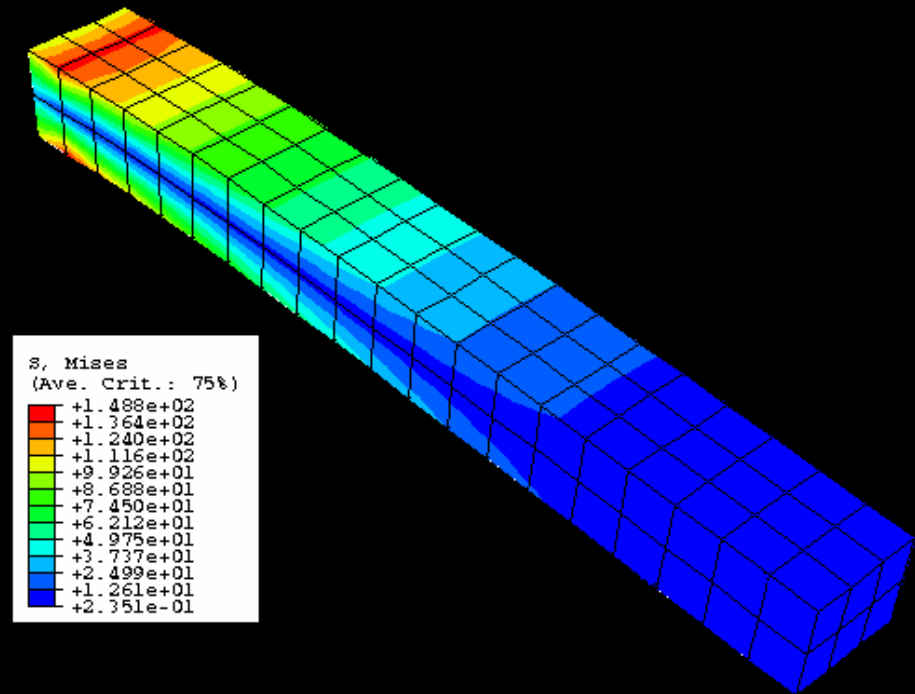
ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231

DR. ANNE NICHOLS

SUMMER 2006

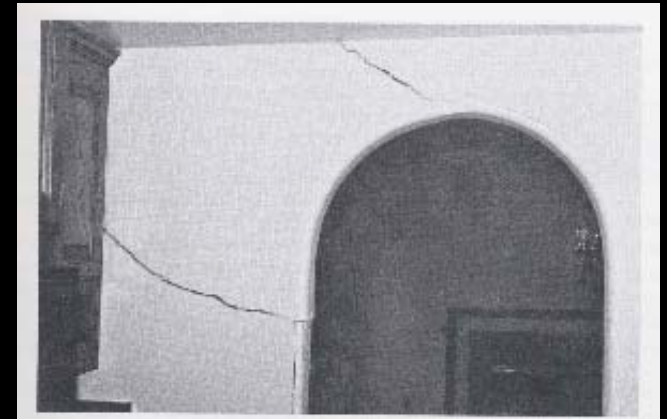
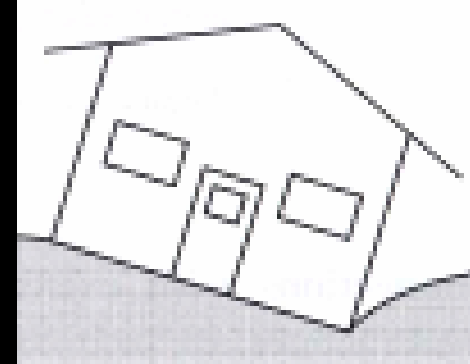
lecture eighteen



beams: deflection & design

Design for Strength +...

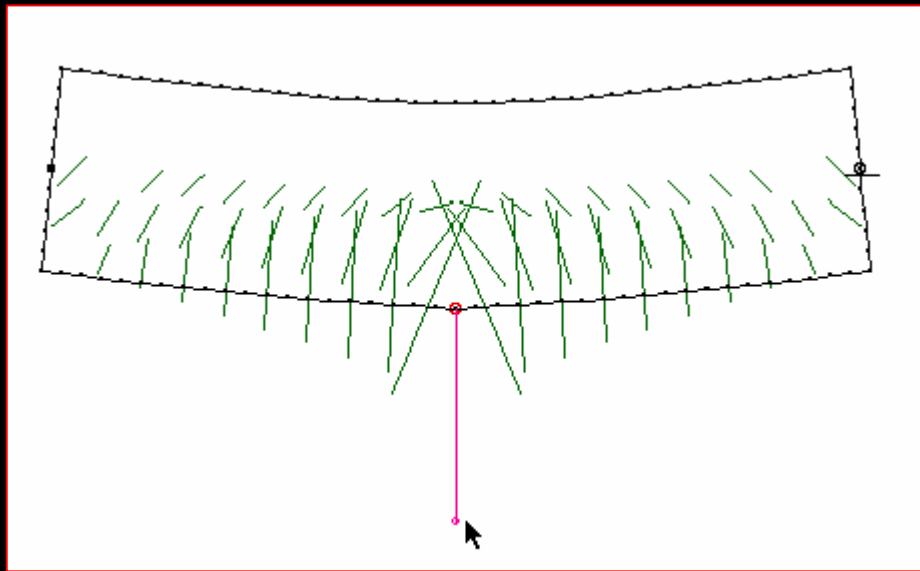
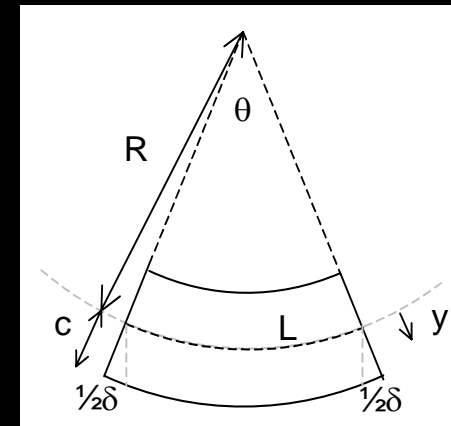
- *strength design*
 - *forces & material*
- *serviceability*
 - *limit deflection and cracking*
 - *control noise & vibration*
 - *no excessive settlement of foundations*
 - *durability*
 - *appearance*
 - *component damage*
 - *ponding*



Beam Deformations

- *curvature relates to*
 - *bending moment*
 - *modulus of elasticity*
 - *moment of inertia*

$$\frac{1}{R} = \frac{M}{EI}$$



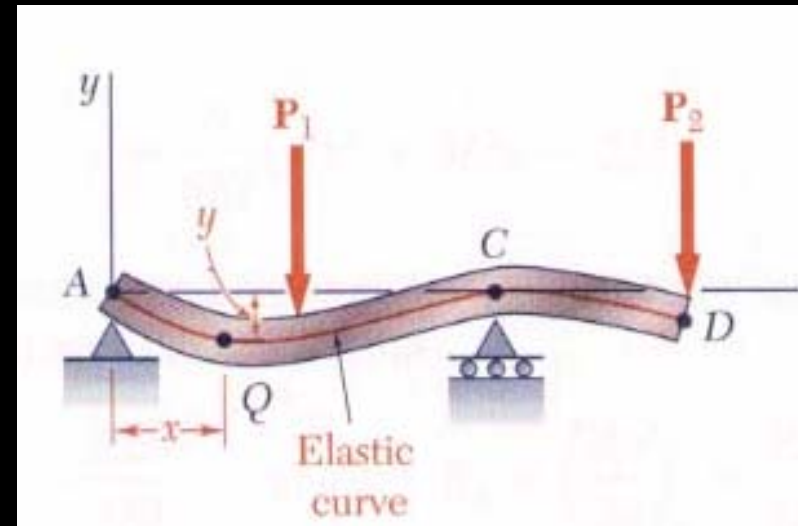
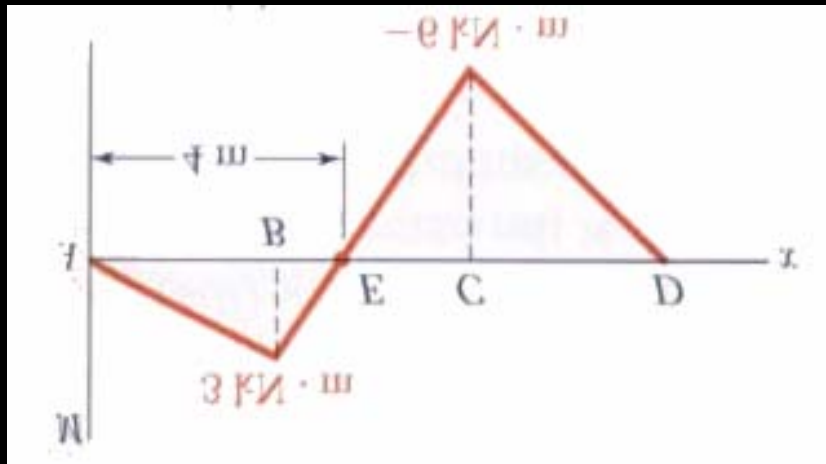
$$\text{curvature} = \frac{M(x)}{EI}$$

$$\theta = \text{slope} = \int \frac{M(x)}{EI} dx$$

$$\Delta = \text{deflection} = \iint \frac{M(x)}{EI} dx$$

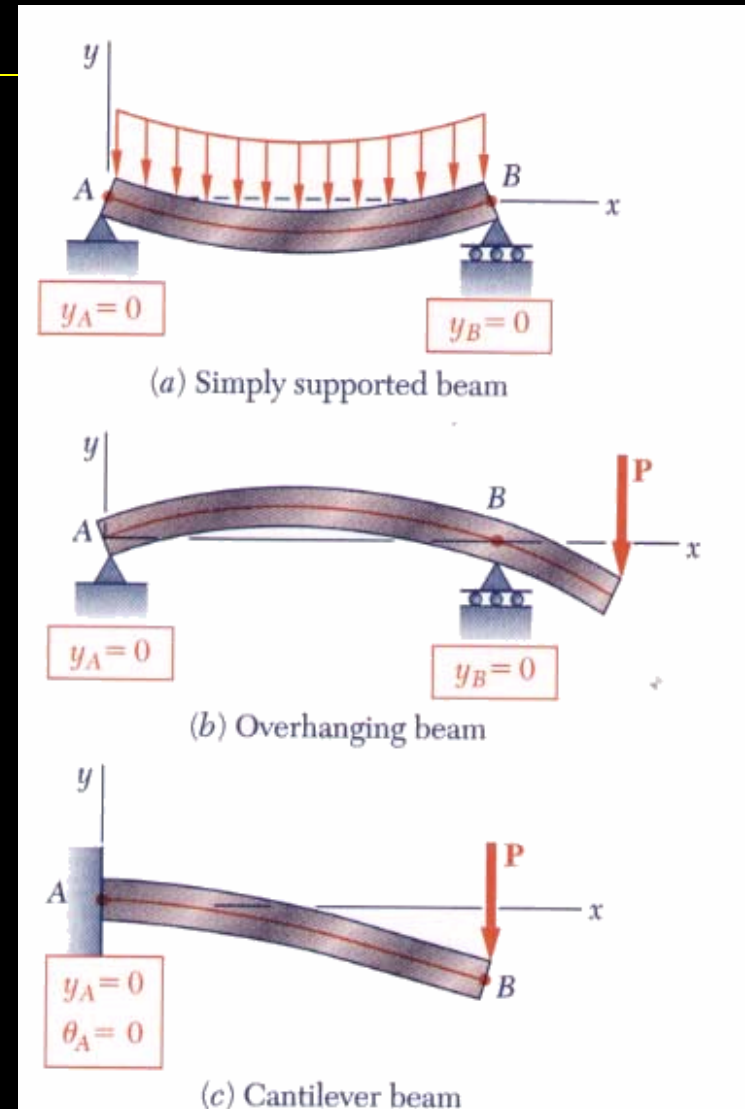
Deflected Shape & $M(x)$

- $-M(x)$ gives shape indication
- boundary conditions must be met



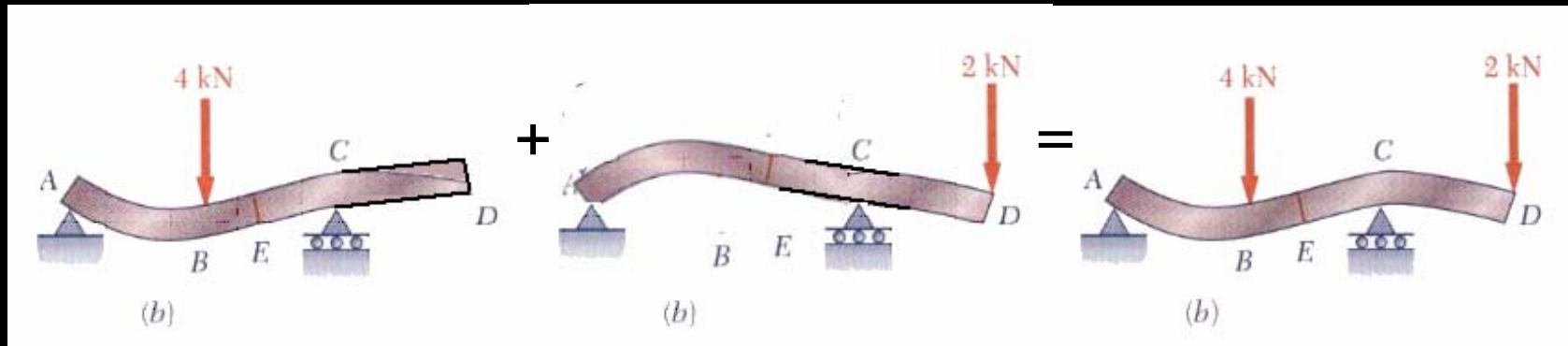
Boundary Conditions

- at pins, rollers, fixed supports: $y = 0$
- at fixed supports: $\theta = 0$
- at inflection points from symmetry: $\theta = 0$
- y_{max} at $\frac{dy}{dx} = 0$



Superpositioning

- if w can be superpositioned
 - θ & y can
 - elastic range only!



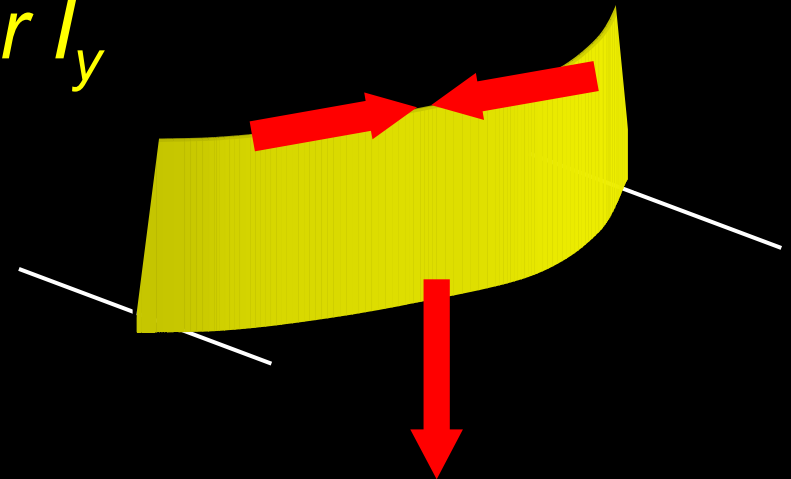
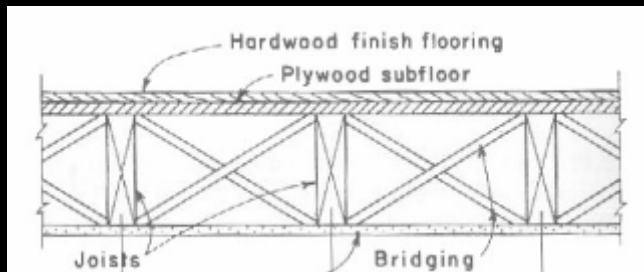
Deflection Limits

- based on service condition, severity

Use	LL only	DL+LL
<i>Roof beams:</i>		
<i>Industrial</i>	<i>L/180</i>	<i>L/120</i>
<i>Commercial</i>		
<i>plaster ceiling</i>	<i>L/240</i>	<i>L/180</i>
<i>no plaster</i>	<i>L/360</i>	<i>L/240</i>
<i>Floor beams:</i>		
<i>Ordinary Usage</i>	<i>L/360</i>	<i>L/240</i>
<i>Roof or floor (damageable elements)</i>		<i>L/480</i>

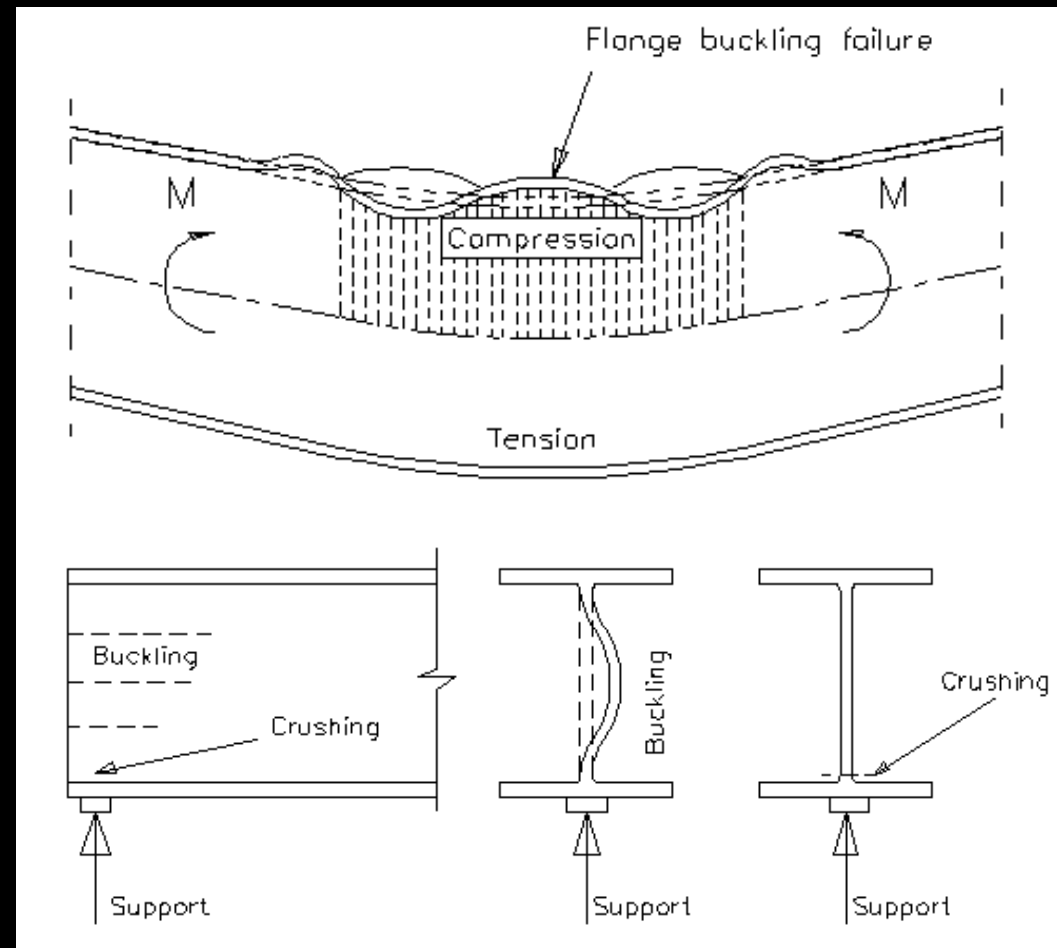
Lateral Buckling

- *lateral buckling caused by compressive forces at top coupled with insufficient rigidity*
- *can occur at low stress levels*
- *stiffen, brace or bigger I_y*



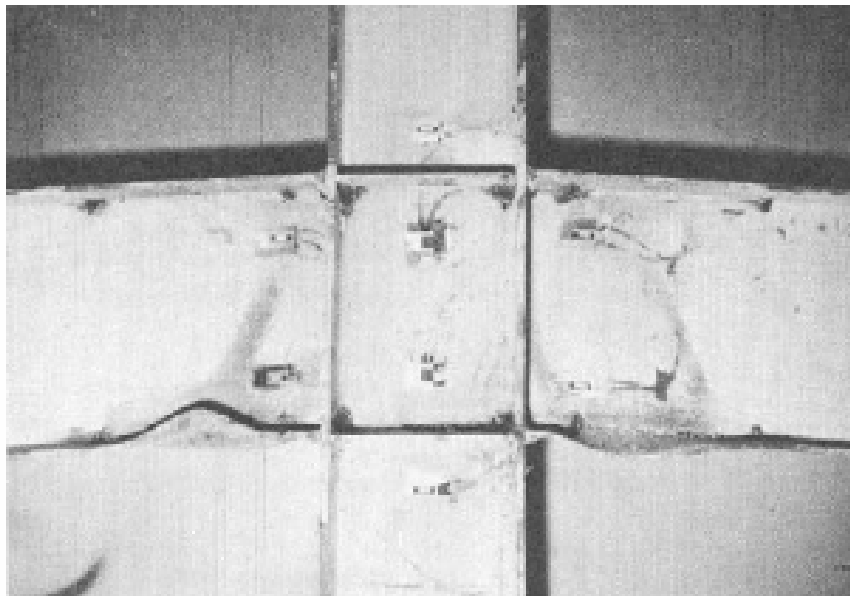
Local Buckling

- *steel I beams*
- *flange*
 - *buckle in direction of smaller radius of gyration*
- *web*
 - *force*
 - *“crippling”*



Local Buckling

- flange



*Figure 2-5. Flange Local Bending Limit State
(Beedle, L.S., Christopher, R., 1964)*

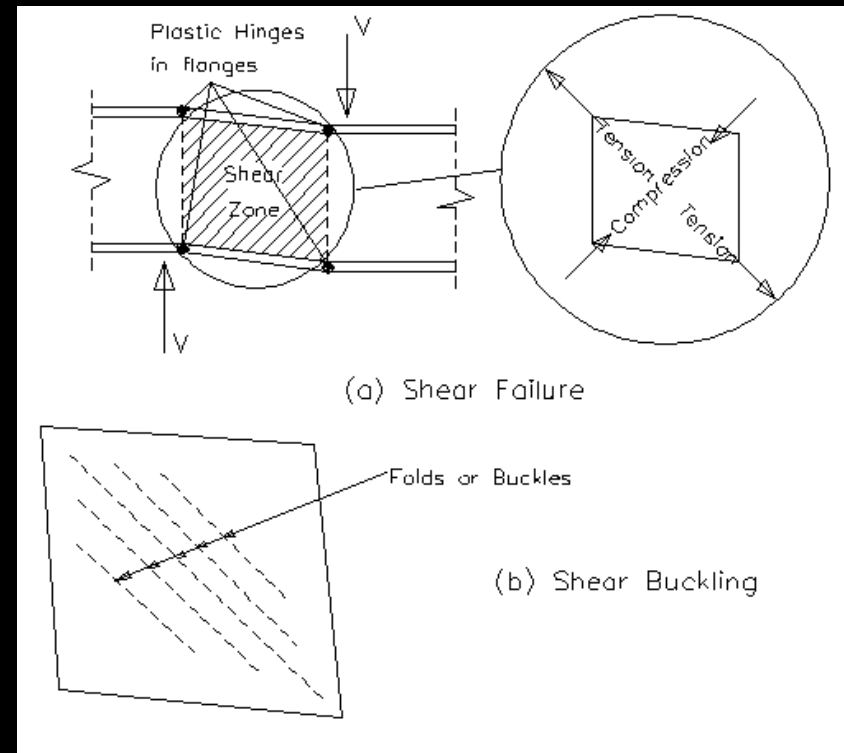
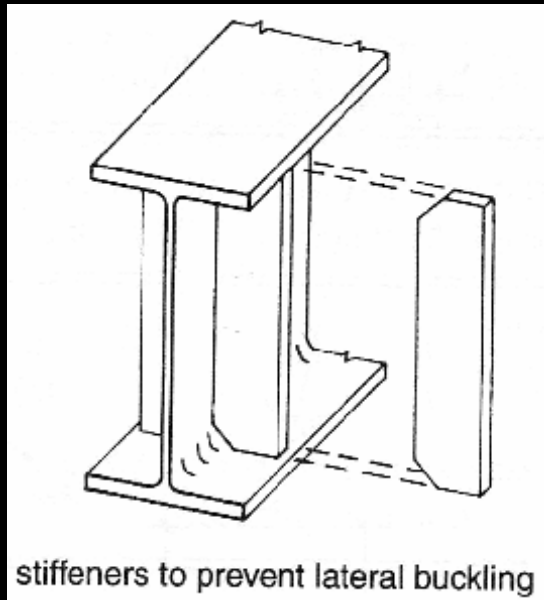
- web



*Figure 2-7. Web Local Buckling Limit State
(SAC Project)*

Shear in Web

- panels in plate girders or webs with large shear
- buckling in compression direction
- add stiffeners



Shear in Web

- *plate girders and stiffeners*



Beam Design

1. Know F_{all} for the material or F_U for LRFD

2. Draw V & M , finding M_{max}



3. Calculate $S_{req'd}$ ($f_b \leq F_b$)

b

4. Determine section size

$$S = \frac{bh^2}{6}$$

Beam Design

4*. Include self weight for M_{max}
– and repeat 3 & 4 if necessary

5. Consider lateral stability

Unbraced roof trusses were blown down in 1999 at this project in Moscow, Idaho.

Photo: Ken Carper



Beam Design

6. Evaluate shear stresses - horizontal

- $(f_v \leq F_v)$

- *W and rectangles*

$$f_{v-\max} = \frac{3V}{2A} \approx \frac{V}{A_{web}}$$

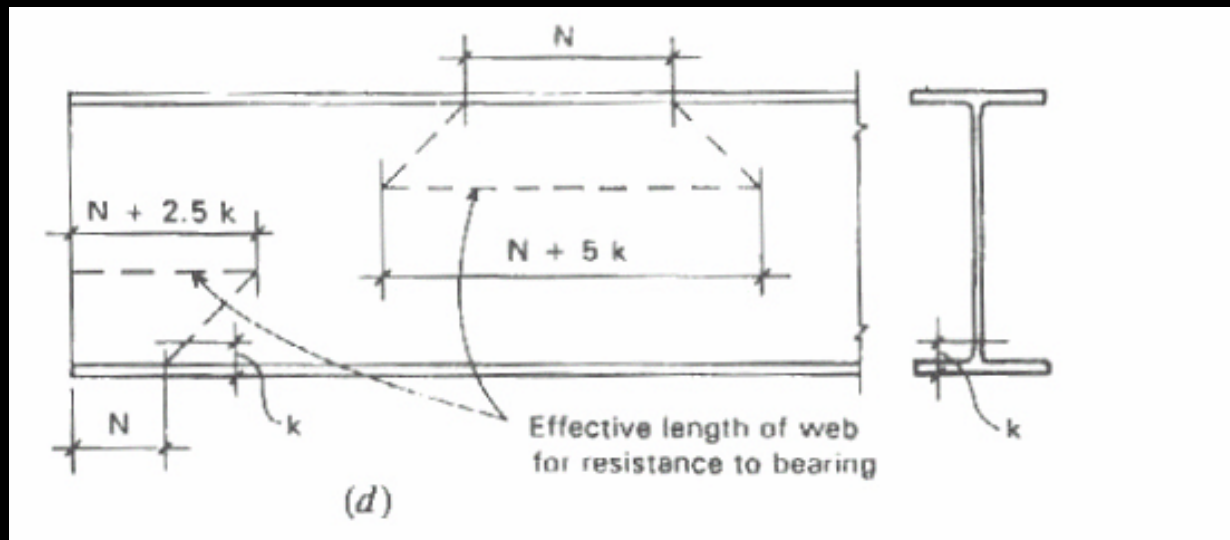
- *thin walled sections*

$$f_{v-\max} = \frac{VQ}{Ib}$$

Beam Design

7. Provide adequate bearing area at supports

$$f_p = \frac{P}{A} \leq F_p$$



Beam Design

8. Evaluate torsion

$$(f_v \leq F_v)$$

- circular cross section

$$f_v = \frac{T\rho}{J}$$

- rectangular

$$f_v = \frac{T}{c_1 ab^2}$$

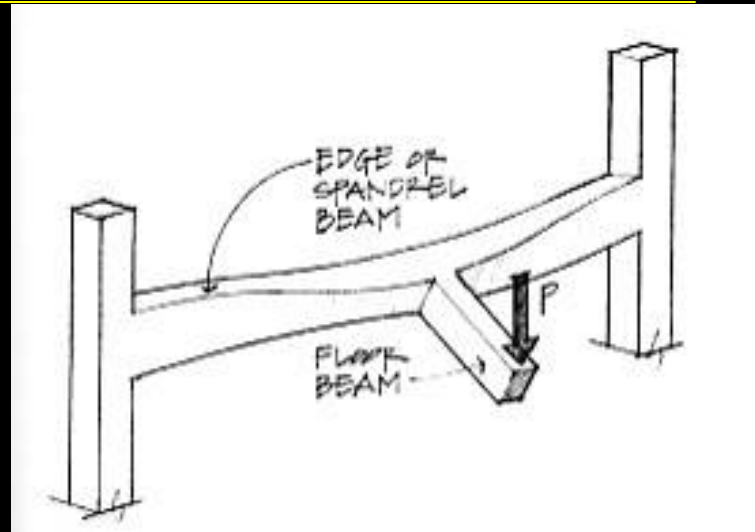
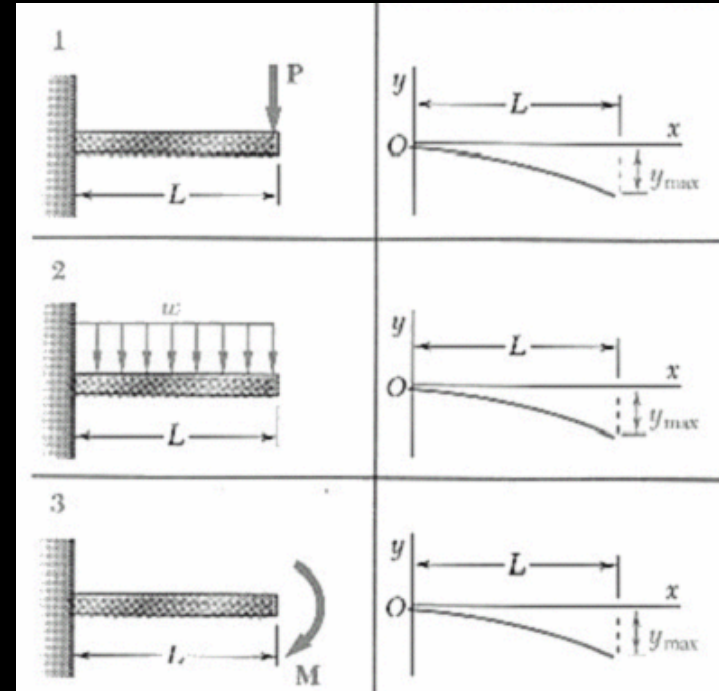
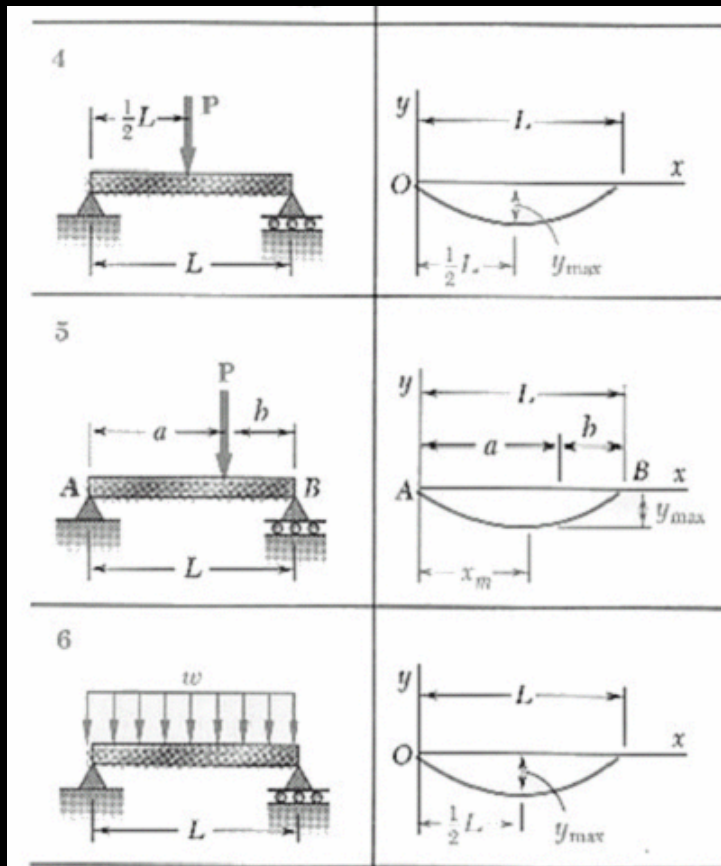


TABLE 3.1. Coefficients for Rectangular Bars in Torsion

a/b	c ₁	c ₂
1.0	0.208	0.1406
1.2	0.219	0.1661
1.5	0.231	0.1958
2.0	0.246	0.229
2.5	0.258	0.249
3.0	0.267	0.263
4.0	0.282	0.281
5.0	0.291	0.291
10.0	0.312	0.312
∞	0.333	0.333

Beam Design

9. Evaluate deflections

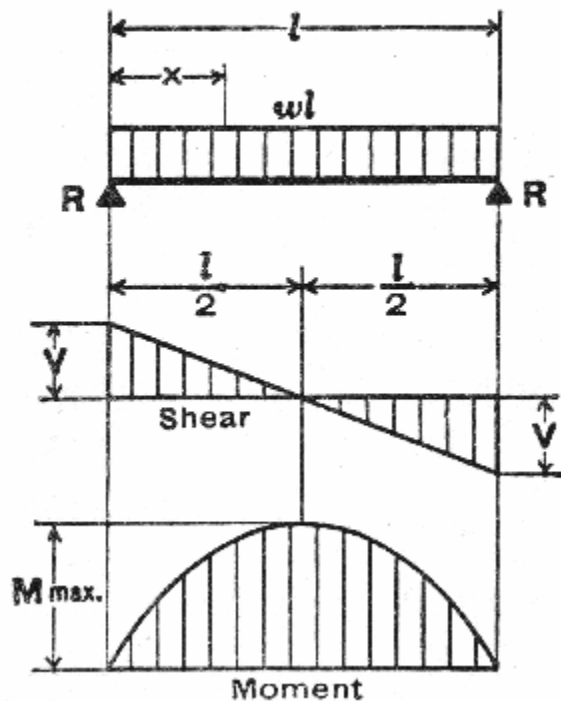


$$y_{max}(x) = \Delta_{actual} \leq \Delta_{allowable}$$

Beam Design

9. – how to read charts

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD



Total Equiv. Uniform Load	$= wl$
$R = V$	$= \frac{wl}{2}$
V_x	$= w \left(\frac{l}{2} - x \right)$
$M_{max.}$ (at center)	$= \frac{wl^2}{8}$
M_x	$= \frac{wx}{2} (l - x)$
$\Delta_{max.}$ (at center)	$= \frac{5wl^4}{384EI}$
Δ_x	$= \frac{wx}{24EI} (l^3 - 2lx^2 + x^3)$