ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231

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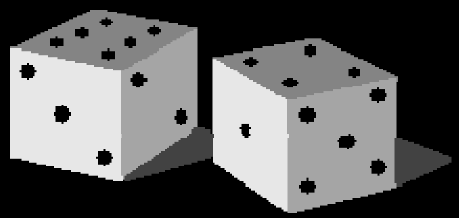
lecture
twenty two

LRFD design of steel beams

Load and Resistance Factor Design

- loads on structures are
  - not constant
  - can be more influential on failure
  - happen more or less often
  - UNCERTAINTY



$$\sum \gamma_i R_i \leq \phi R_n$$

factored load combination

ϕ - resistance factor

γ - load factors for types of loads (R)

R_n – nominal strength

Load Types

- *D = dead load*
- *L = live load*
- L_r *= live roof load*
- *W = wind load*
- *S = snow load*
- *E = earthquake load*
- *R = rainwater load or ice water load*

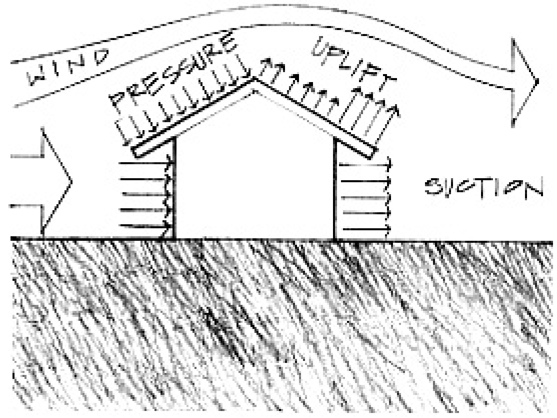


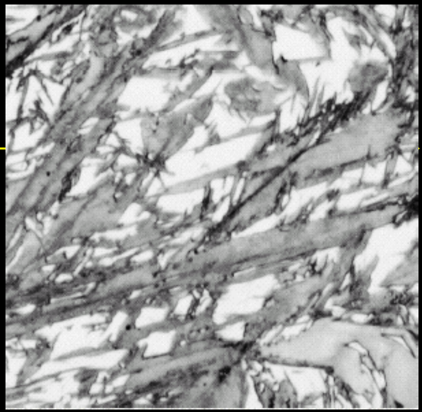
Figure 1.13 Wind loads on a structure.

Load Combinations

ASCE-7 (2002)

- *"summation" means AND (combine)*
  - $1.4(D + F)$
  - $1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R)$
  - $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.8W)$
  - $1.2D + 1.6W + L + 0.5(L_r \text{ or } S \text{ or } R)$
  - $1.2D + 1.0E + L + 0.2S$
  - $0.9D + 1.6W + 1.6H$
  - $0.9D + 1.0E + 1.6H$

Steel Materials



- ASTM A36 – carbon
  - plates, angles
  - F_y = 36 ksi & F_u = 58 ksi
- ASTM A572 – high strength low-alloy
  - some beams
  - F_y = 60 ksi & F_u = 75 ksi
- ASTM A992 – for building framing
  - most beams
  - F_y = 50 ksi & F_u = 65 ksi

Flexure

- limit is in plastic stress range

$$\Sigma\gamma_i R_i = M_u \le \phi_b M_n = 0.9 F_y Z$$

M_u - maximum moment

ϕ_b - resistance factor for bending = 0.9

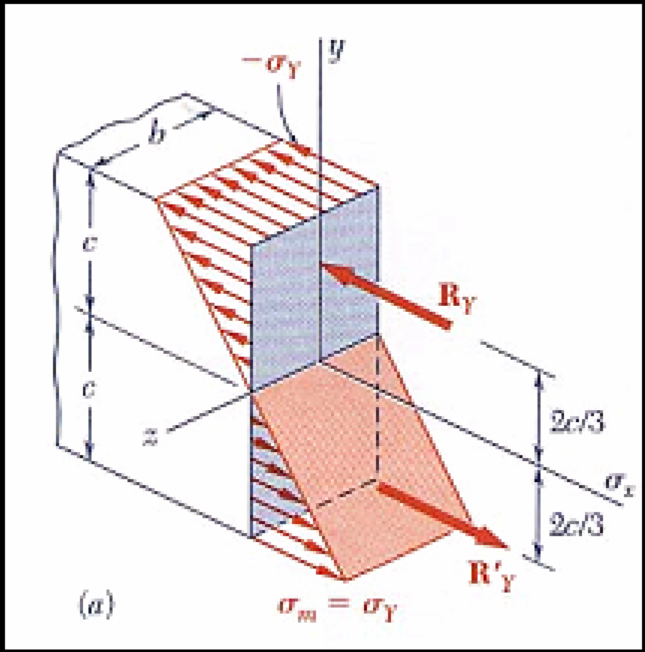
M_n - nominal moment (ultimate capacity)

F_y - yield strength of the steel

Z - plastic section modulus*

Internal Moments - at yield

- *material hasn't failed*

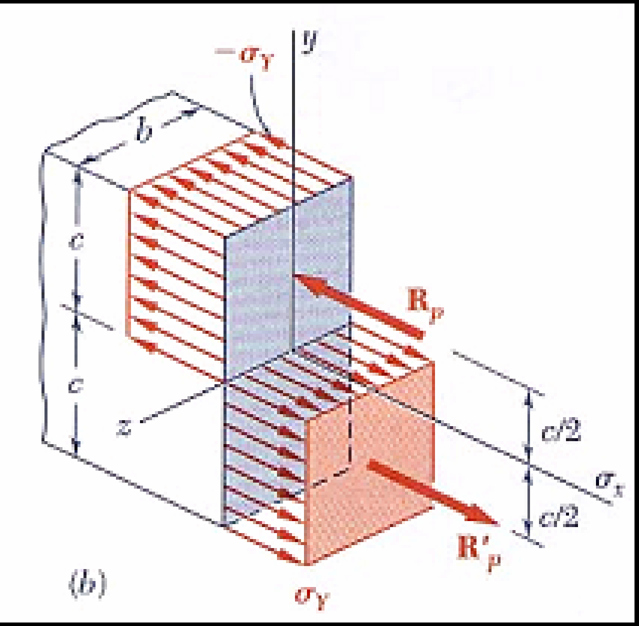


$$M_y = \frac{I}{c} f_y = \frac{bh^2}{6} f_y$$

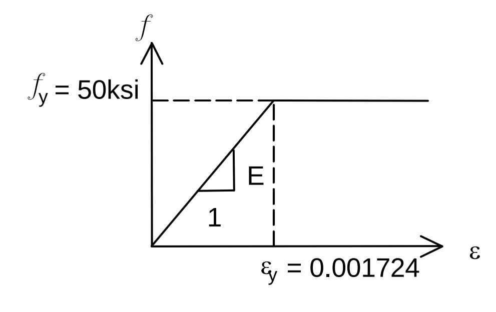
$$= \frac{b(2c)^2}{6} f_y = \frac{2bc^2}{3} f_y$$

Internal Moments - ALL at yield

- all parts reach yield
- plastic hinge forms
- ultimate moment
- $A_{tension} = A_{compression}$

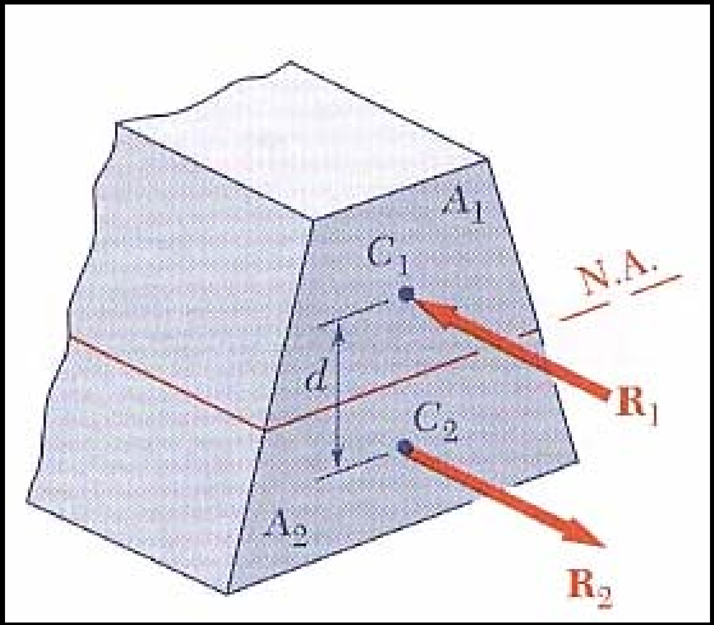


$$M_p = bc^2 f_y = \frac{3}{2} M_y$$



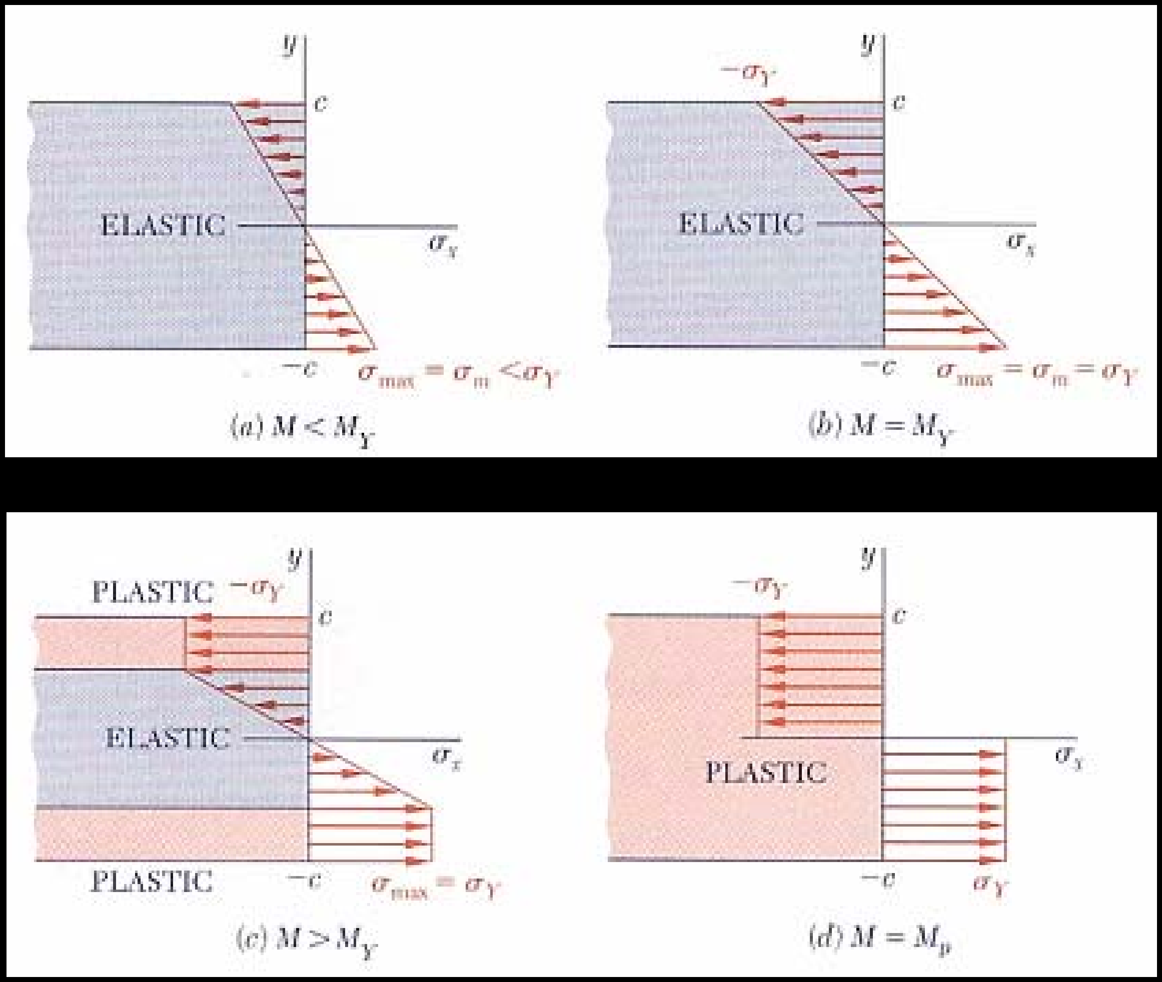
n.a. of Section at Plastic Hinge

- cannot guarantee at centroid
- $f_y A_1 = f_y A_2$
- moment found from yield stress times moment area



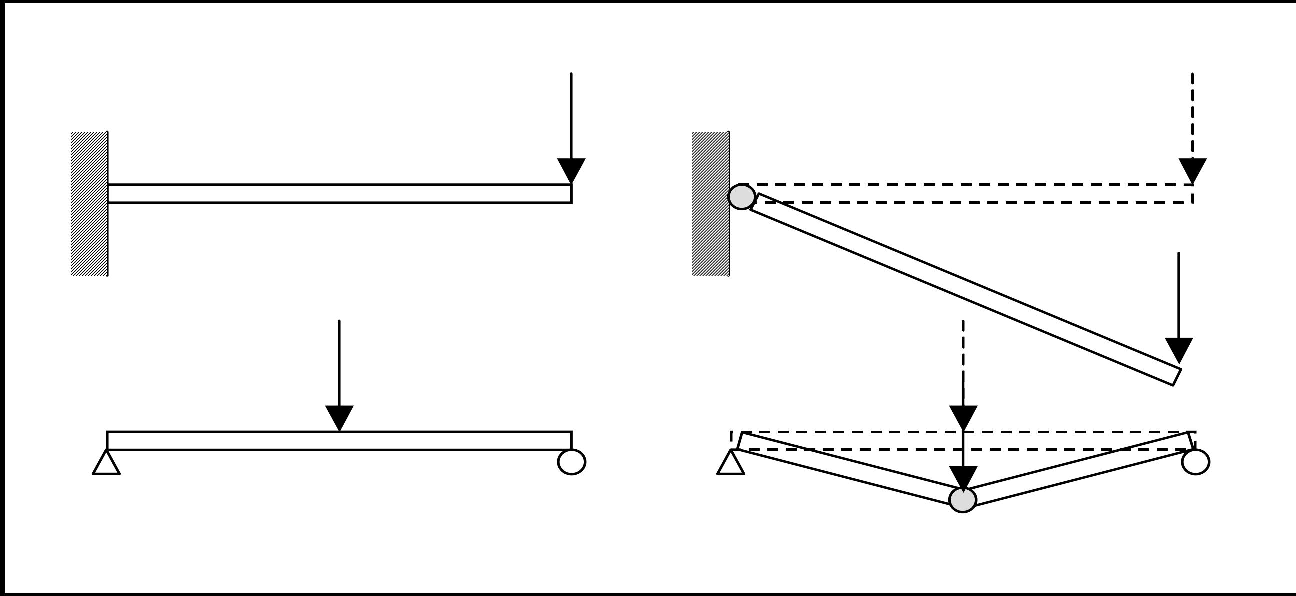
$$M_p = f_y A_1 d = f_y \sum_{n.a} A_i d_i$$

Plastic Hinge Development



Plastic Hinge Examples

- *stability can be effected*



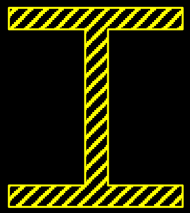
Plastic Section Modulus

- *shape factor, k*

$$k = {M_p}/{M_y}$$

= 3/2 for a rectangle

$\approx$ *1.1 for an* I



$$k = {Z}/{S}$$

- *plastic modulus, Z*

$$Z = \frac{M_p}{f_y}$$

Shear

$$\Sigma \gamma_i R_i = V_u \le \phi_v V_n = 0.9(0.6 F_{yw} A_w)$$

V_u - maximum shear

ϕ_v - resistance factor for shear = 0.9

V_n - nominal shear

F_{yw} - yield strength of the steel in the web

A_w - area of the web = $t_w d$

Flexure Design

- limit states for beam failure
  1. yielding
  2. lateral-torsional buckling*
  3. flange local buckling
  4. web local buckling
- minimum M_n governs

$$\Sigma \gamma_i R_i = M_u \leq \phi_b M_n$$

Lateral Torsional Buckling

$$M_n = C_b \left[\begin{matrix} \textit{moment based on} \\ \textit{lateral buckling} \end{matrix} \right] \leq M_p$$

$$C_b = \frac{12.5 M_{max}}{2.5 M_{max} + 2M_A + 4M_B + 3M_C}$$

C_b = modification factor

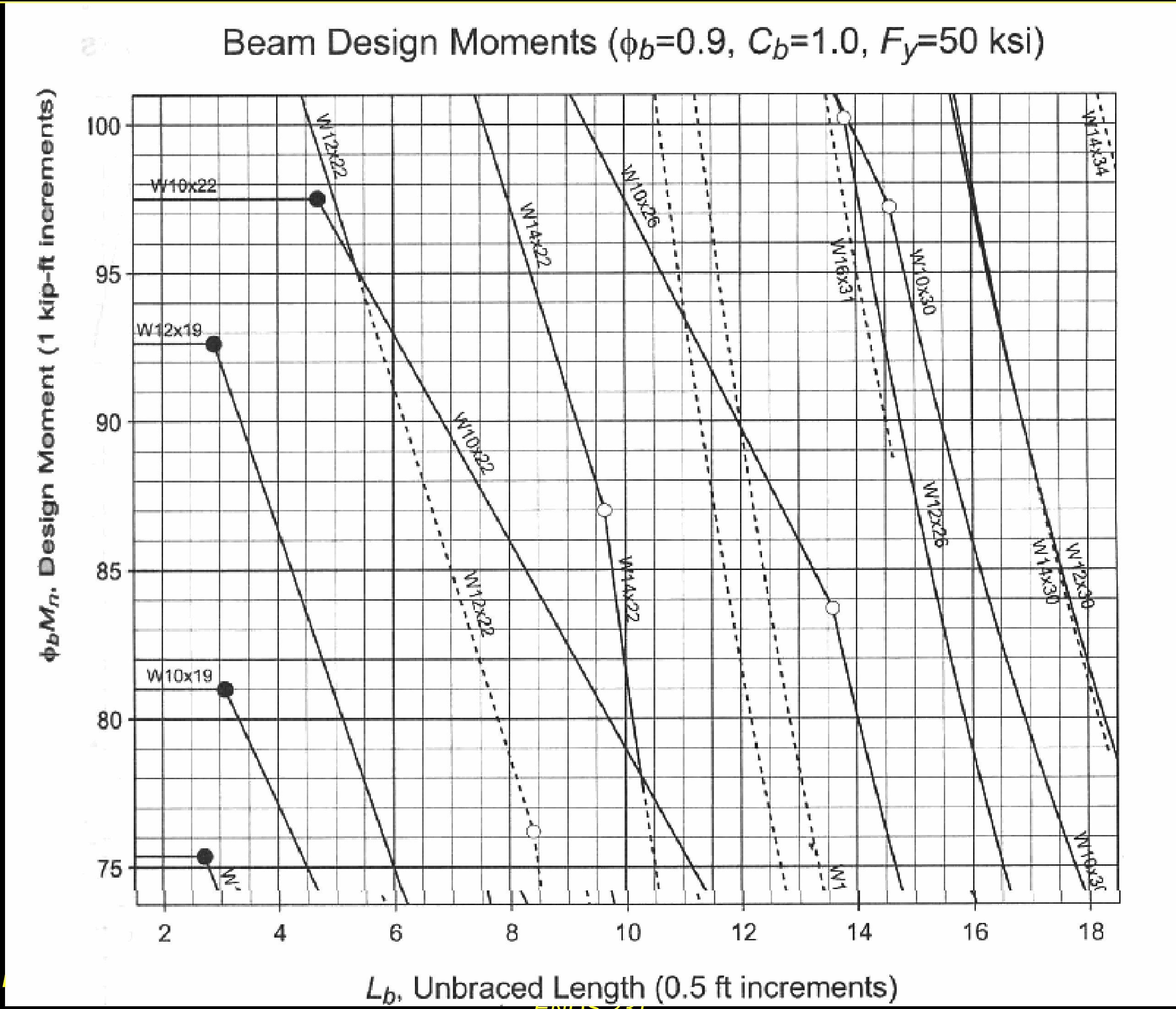
M_{max} - |max moment|, unbraced segment

M_A - |moment|, 1/4 point

M_B = |moment|, center point

M_C = |moment|, 3/4 point

Beam Design Charts



Charts & Deflections

- *beam charts*
  - *solid line is most economical*
  - *dashed indicates there is another more economical section*
  - *self weight is included in M_n*
- *deflections*
  - *no factors are applied to the loads*
  - *often governs the design*