ARCHITECTURAL STRUCTURES I: STATICS AND STRENGTH OF MATERIALS

ENDS 231

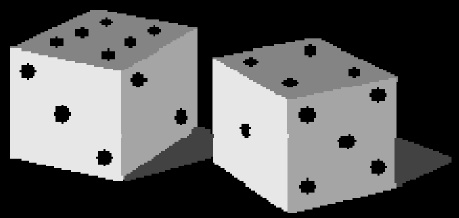
DR. ANNE NICHOLS

SPRING 2008

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*

$$\Sigma \gamma_i R_i \leq \phi R_n$$

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

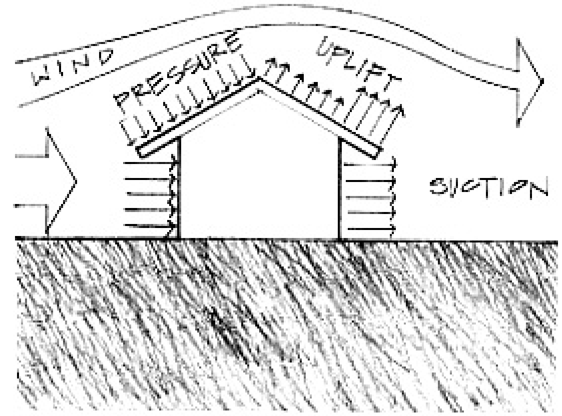


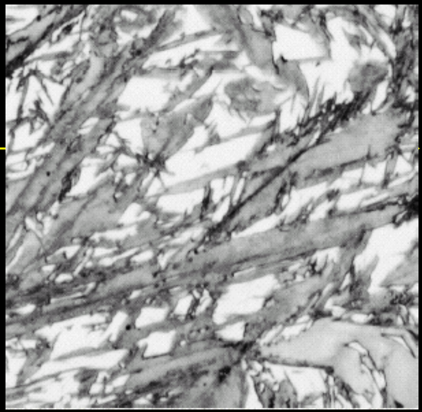
Figure 1.13 Wind loads on a structure.

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)

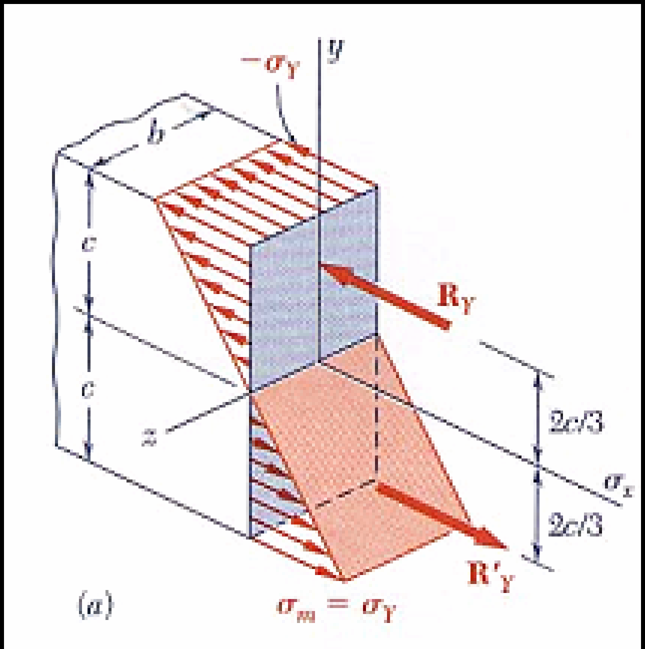
F_y - yield strength of the steel

*Z - plastic section modulus**

Internal Moments - at yield

- material hasn't failed

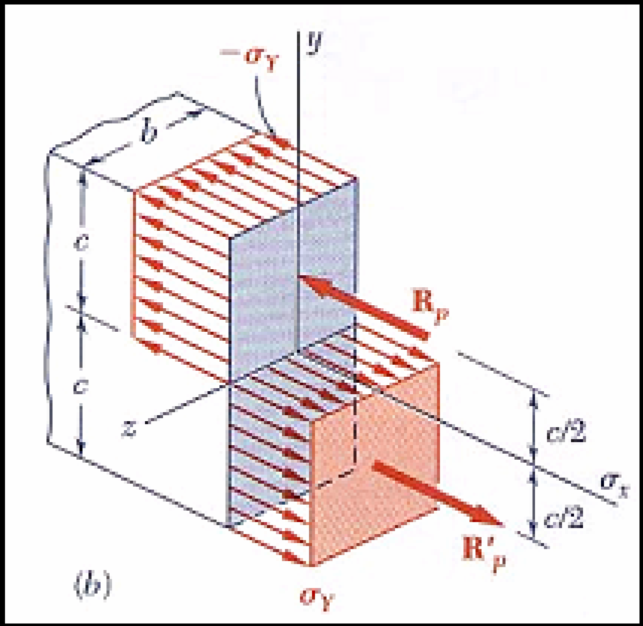
$$M_y = \frac{I}{c} f_y = \frac{bh^2}{6} f_y$$



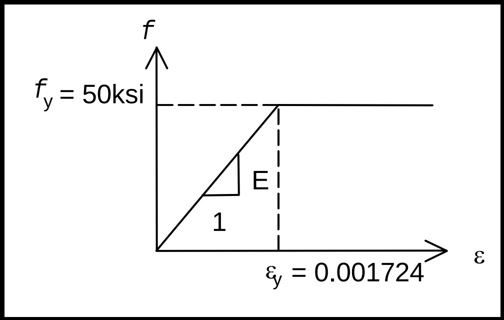
$$= \frac{b(2c)^2}{6} f_y = \frac{2bc^2}{3} f_y$$

Internal Moments - ALL at yield

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

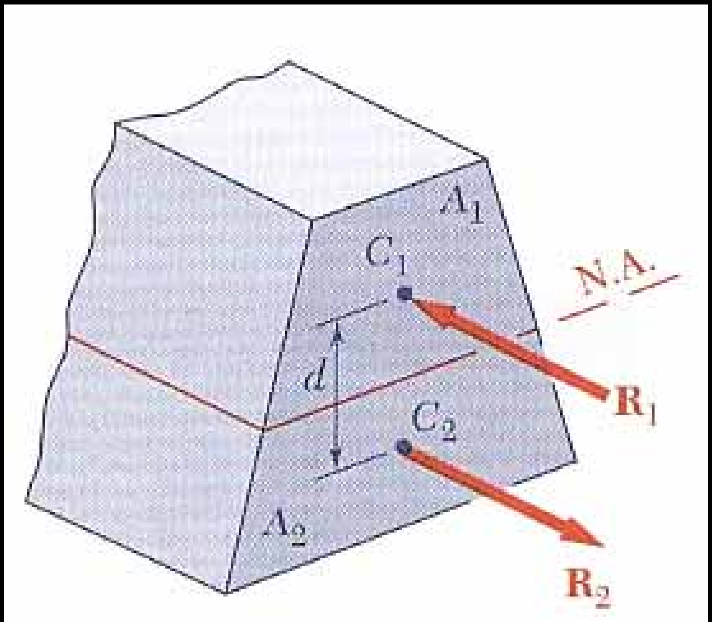


$$M_p = bc^2 f_y = \frac{3}{2} M_y$$



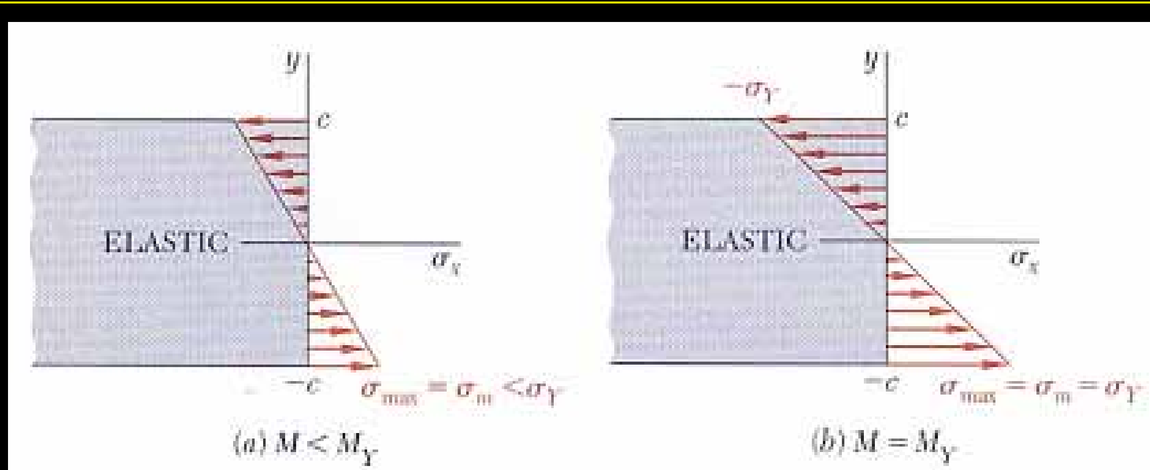
n.a. of Section at Plastic Hinge

- *cannot guarantee at centroid*
- $f_y A_1 = f_y A_2$
- *moment found from yield stress times <u>moment area</u>*

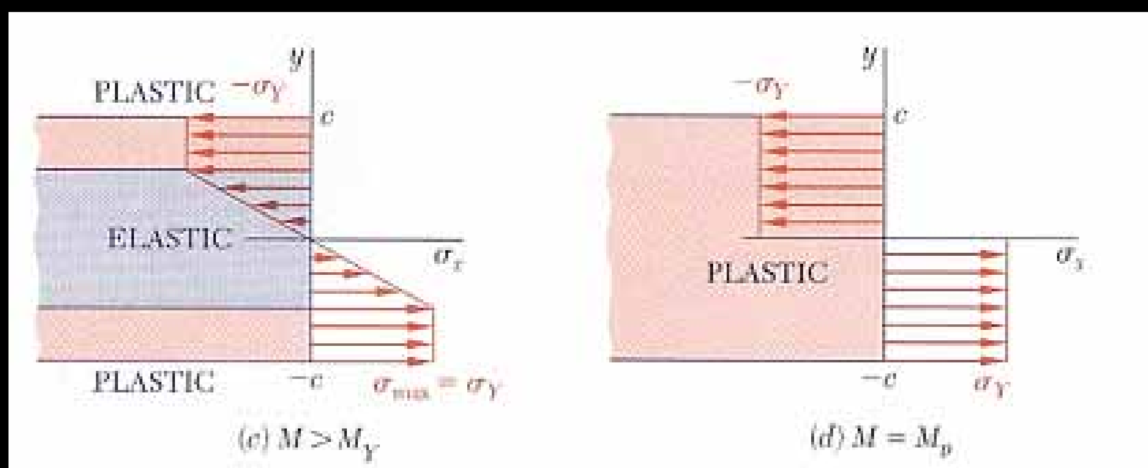


$$M_p = f_y A_1 d = f_y \sum_{n.a} A_i d_i$$

Plastic Hinge Development



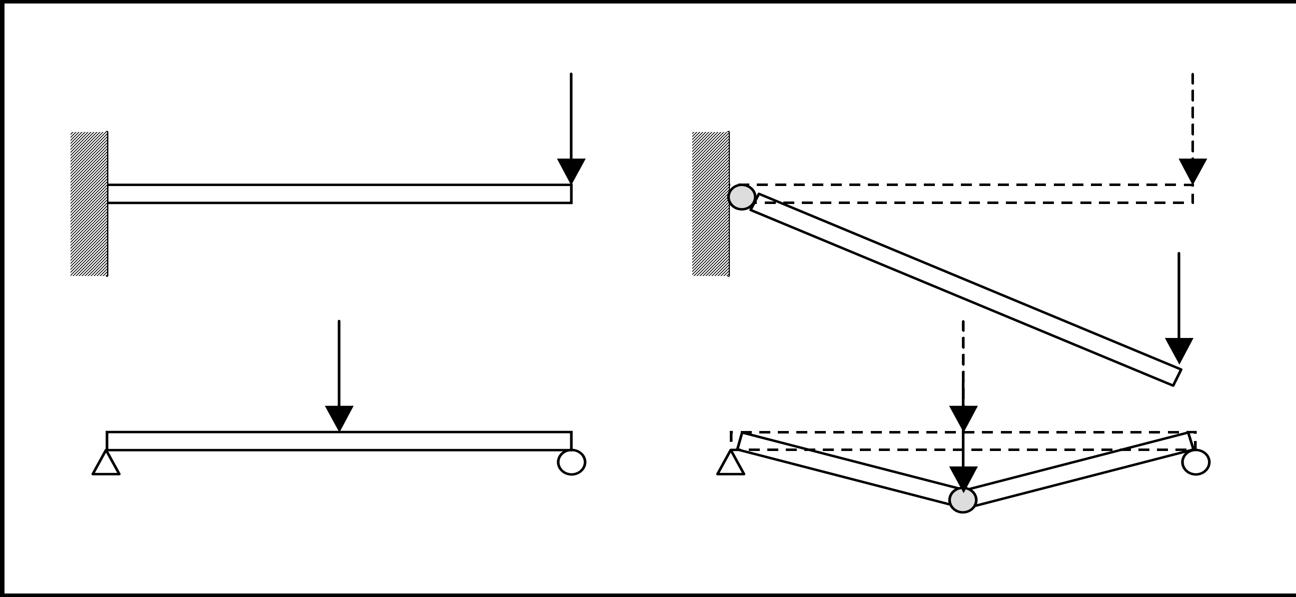
(a) $M < M_Y$ (b) $M = M_Y$



(c) $M > M_Y$ (d) $M = M_p$

Plastic Hinge Examples

- *stability can be effected*



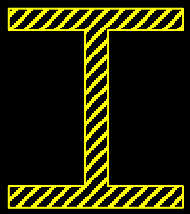
Plastic Section Modulus

- shape factor, k

$$k = M_p \big/ M_y$$

= 3/2 for a rectangle

$\approx$ 1.1 for an I



$$k = Z \big/ S$$

- plastic modulus, Z

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

Shear

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

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

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

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

C_b = modification factor

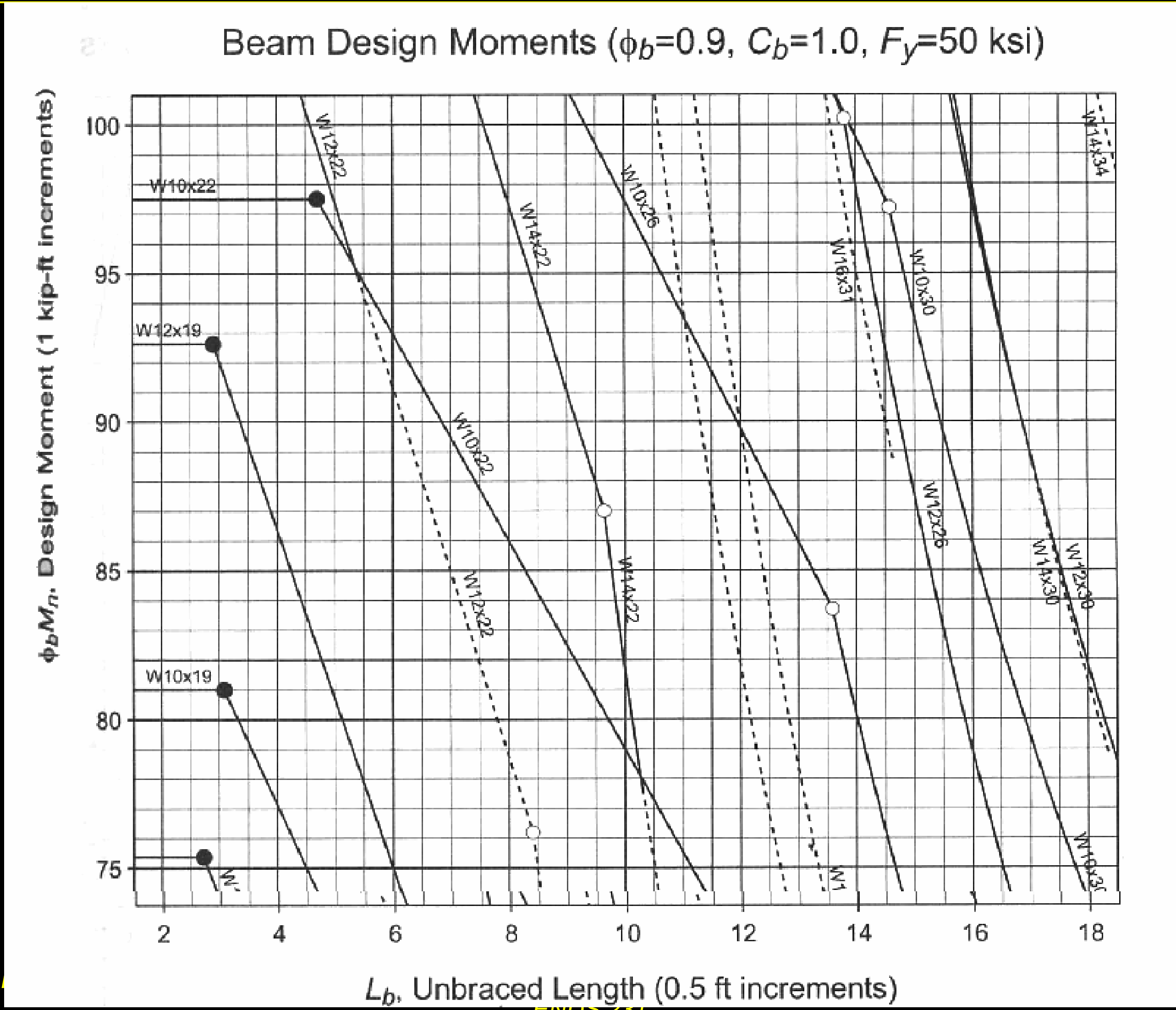
M_{max} - |max moment|, unbraced segment

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*