

CHAPTER 5

Strength requirement

AISC MAN.: CHAP F & B ← class. of shape

BEAMS: A member supporting transverse load to the length of the member, results in "flexing" or "bending"

⇒ Flexural Members

Transverse loads cause two dominant internal forces:

1) Shear

2) Moment ← dominant force in steel

Beams can have axial load → Beam-columns

CHAP F: Applicable Part of F are determined by:

1) Shape

2) Class of shape - slender/compactness

CHAP B: Table B4.1b (Table B4.1a is for comp.)

- compact $\lambda \leq \lambda_p$ $\rightarrow$ can develop the full plastic moment, doesn't buckle
- non-compact $\lambda_p < \lambda \leq \lambda_r$ $\rightarrow$ plastic & elastic behavior, controlled by inelastic buckling
- slender $\lambda > \lambda_r$ $\rightarrow$ elastic behavior, elastic buckling

W-Shape

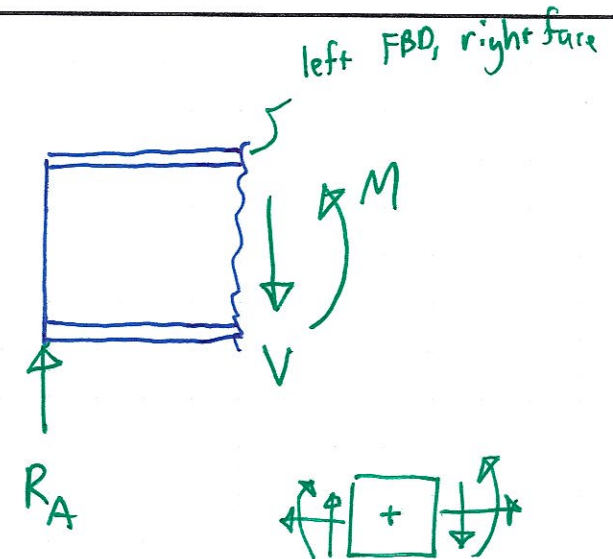
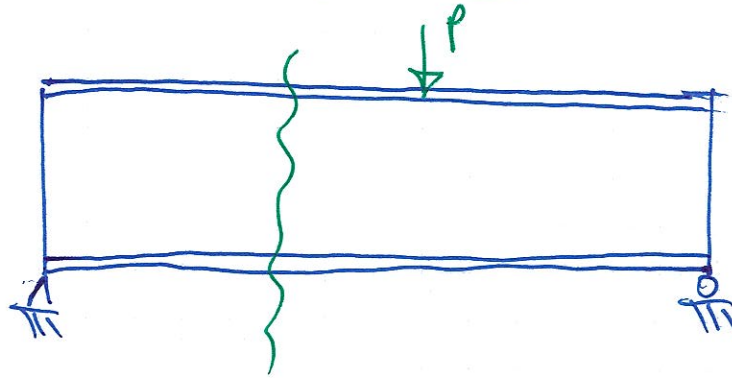
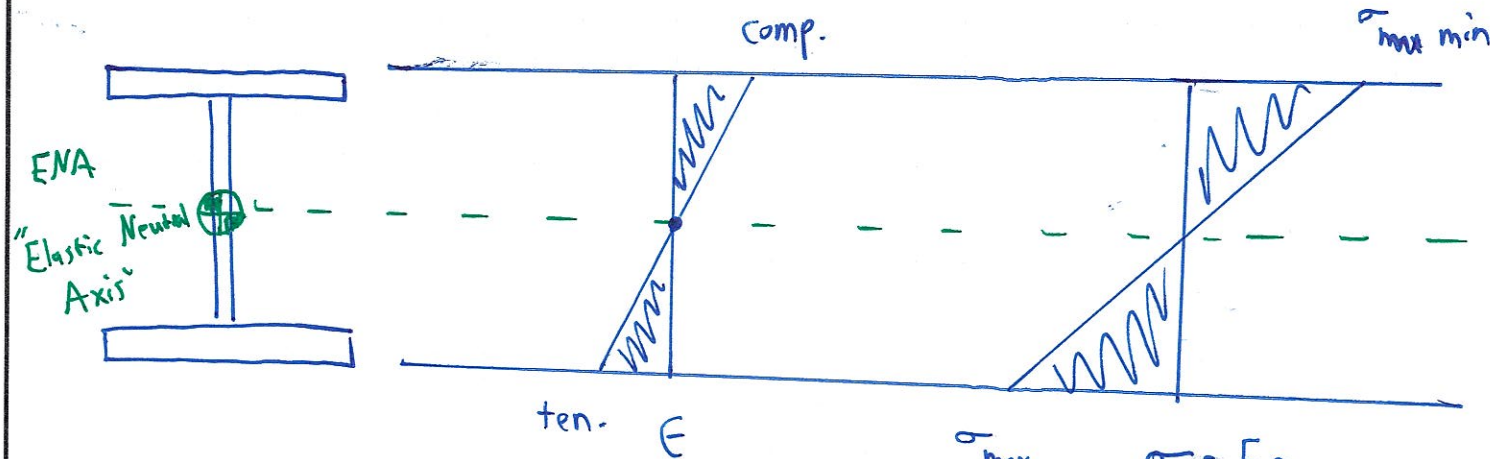
CASE 10: Flange $\frac{b_f}{2t_f}$

CASE 15: WEB $\frac{h}{t_w}$

DESIGN CAPACITY $\sim$ design Mom. Capacity

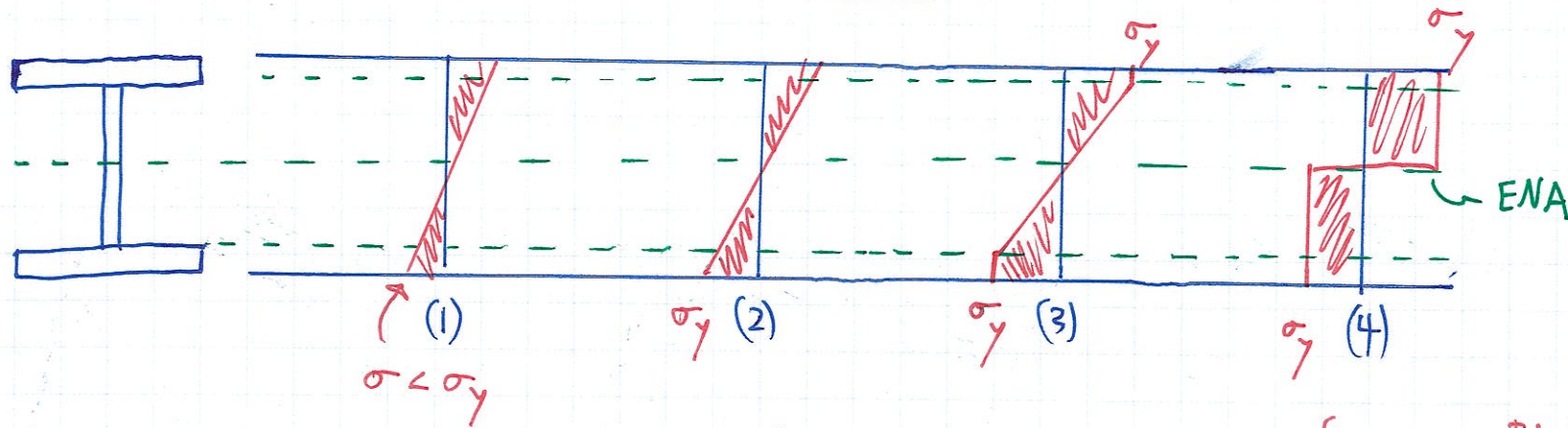
$$M_u = \phi_b M_n \quad \text{Nominal Mom. Capacity}$$

$\uparrow$ $\uparrow$
 Factored Mom. 0.9

BENDING STRESS & PLASTIC MOMENTCONSIDERCROSS-SECTION

$$\sigma = \frac{My}{I} ; \sigma_{max} = \frac{Mc}{I} = \frac{M}{S} \quad \text{section modulus (Elastic)} = \frac{I}{c}$$

AS LOAD INCREASES, BENDING MOM. INCREASES ALSO



$$\sigma = \frac{My}{I} = \frac{M}{S}$$

→ INCREASE IN MOM.

- 1) $M < f_y S_x$ "fully elastic"
- 2) $M_y = f_y S_x$ "first yield"
- 3) $M_y < M < M_p$ "Elastic/Plastic Behavior"
- 4) $M_p = Z_x f_y$ "fully plastic"

↑
Plastic Section Modulus

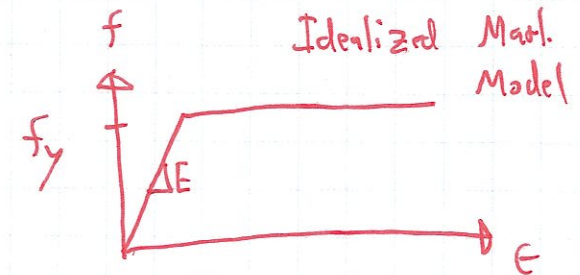


Diagram illustrating the plastic state of a beam cross-section. The cross-section is divided into two equal halves by the Plastic Neutral Axis (PNA). The top half is in compression, labeled $f_y(\text{comp})$, and the bottom half is in tension, labeled $f_y(\text{ten})$. The distance from the PNA to the extreme top and bottom fibers is labeled a . The resultant forces for compression and tension are labeled $C = A_{\text{comp}} f_y$ and $T = A_{\text{ten}} f_y$ respectively. The total force is labeled $\text{force} \Rightarrow \sigma_y A$.

Below the diagram, the equations are derived:

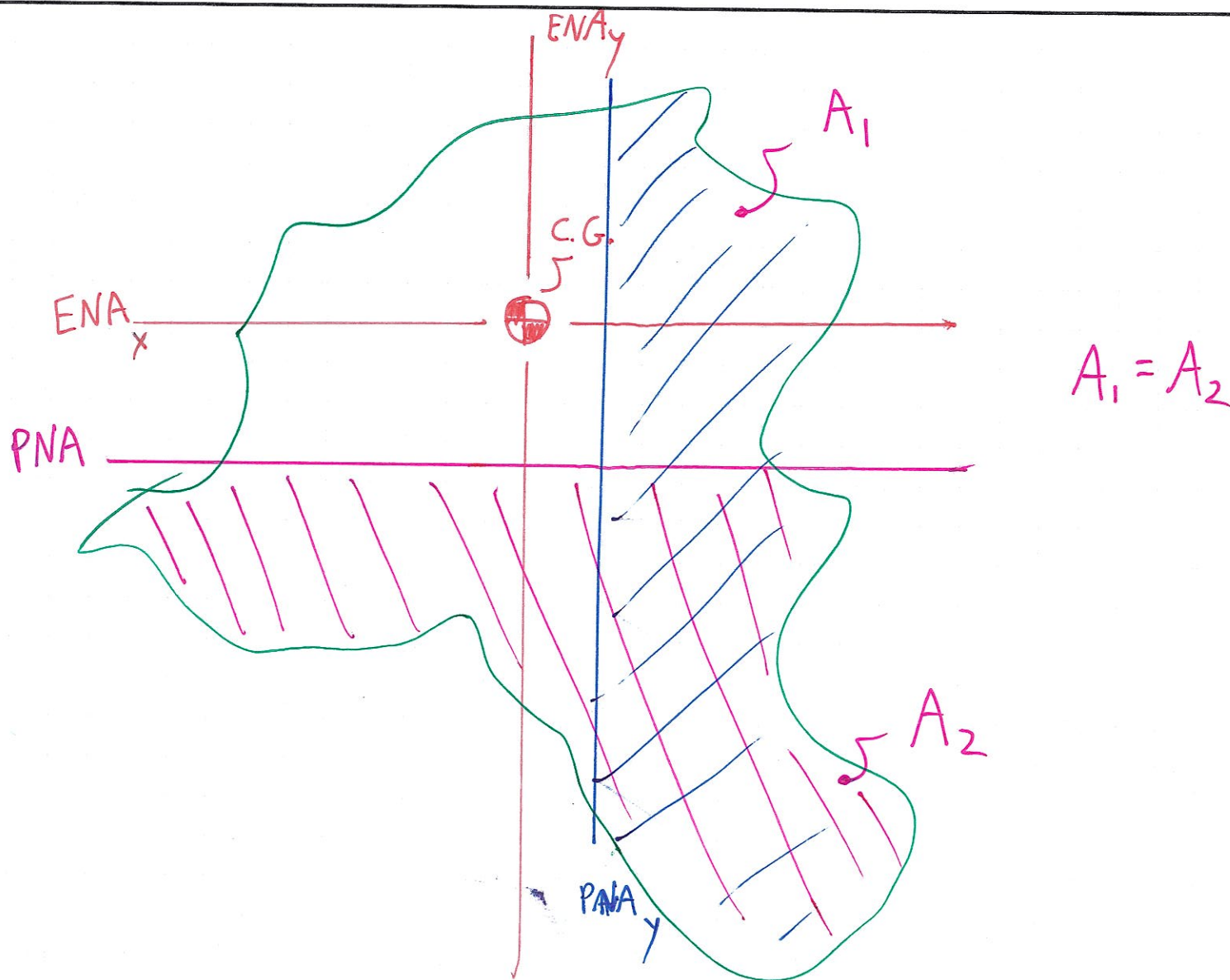
$$\sum F_x = 0; \quad C = T$$

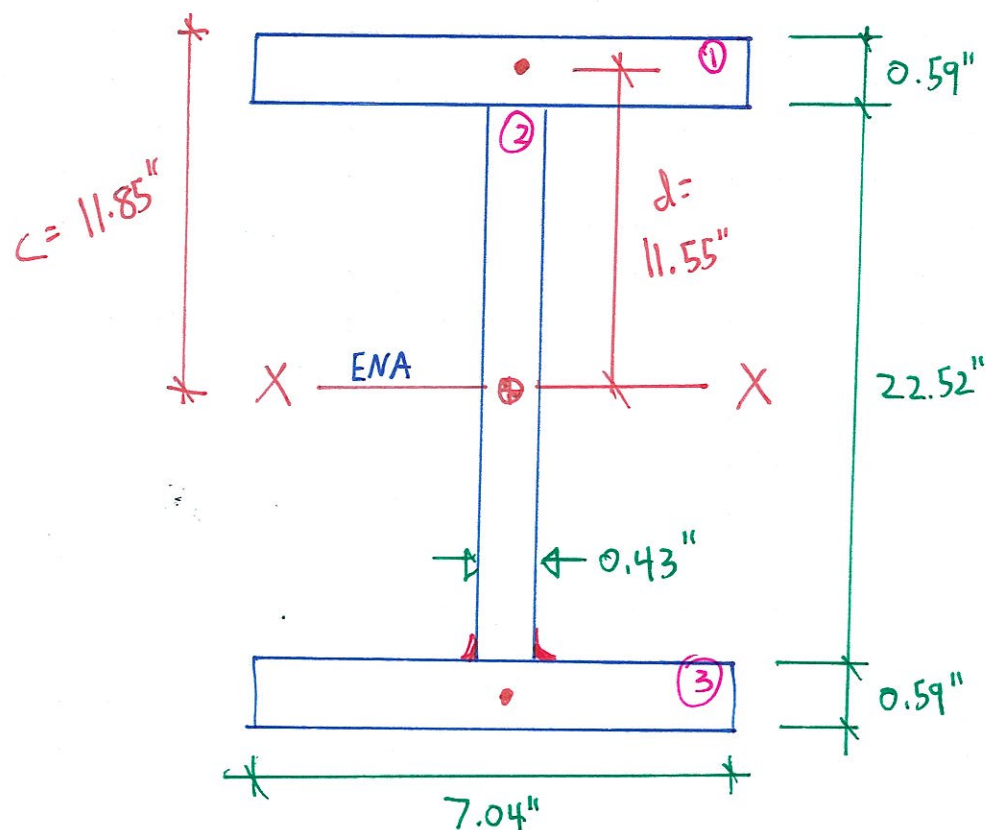
$$A_{\text{comp}} f_y = A_{\text{ten}} f_y \Rightarrow A_c = A_t$$

$\therefore$ PNA divides the CSA into two equal halves

$$M_p = (C \text{ or } T) a = f_y A_{\text{ten}} a = f_y \left(\frac{A_g}{2} \right) a$$

The term $\left(\frac{A_g}{2} \right)$ is circled in red, with a red arrow pointing to Z_x .



EXAMPLEGIVEN: A W24 X 62, A992 Steel BeamREQD: FOR the x-x axis: a) S_x c) M_y e) shape factor
b) Z_x d) M_p SOLN: W24 X 62

$$a) S_x = \frac{I_x}{C}$$

$$I_x = \underbrace{\left[\frac{1}{12} (7.04") (0.59")^3 + (0.59") (7.04") (11.55")^2 \right]}_{\text{Flanges}}$$

$$+ \left[\frac{1}{12} (0.43") (22.52")^3 \right]$$

Web

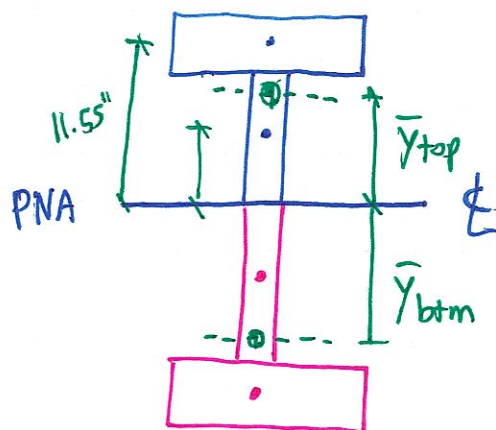
$$I_x = 1519 \text{ in}^4$$

$$S_x = \frac{1519 \text{ in}^4}{11.85"} = 128.2 \text{ in}^3$$

(AISC $S_x = 131 \text{ in}^3$)

$$b) Z_x = \frac{A_g}{2} q$$

$$\frac{A_g}{2} = \frac{(2)(0.59'')(7.04'') + 0.43''(22.52'')}{2} = 8.995 \text{ in}^2$$



$$q = \bar{y}_{top} + \bar{y}_{botm}$$

$$\bar{y} = \frac{(7.04'')(0.59'')(11.55'') + (0.43'')\left(\frac{22.52''}{2}\right)\left(\frac{22.52''}{4}\right)}{(7.04'')(0.59'') + 0.43''\left(\frac{22.52''}{2}\right)}$$

$$= 8.367''$$

$$q = 2\bar{y} = 16.734 \text{ in}$$

$$Z_x = (8.995 \text{ in}^2)(16.734 \text{ in}) = \underline{\underline{150.5 \text{ in}^3}}$$

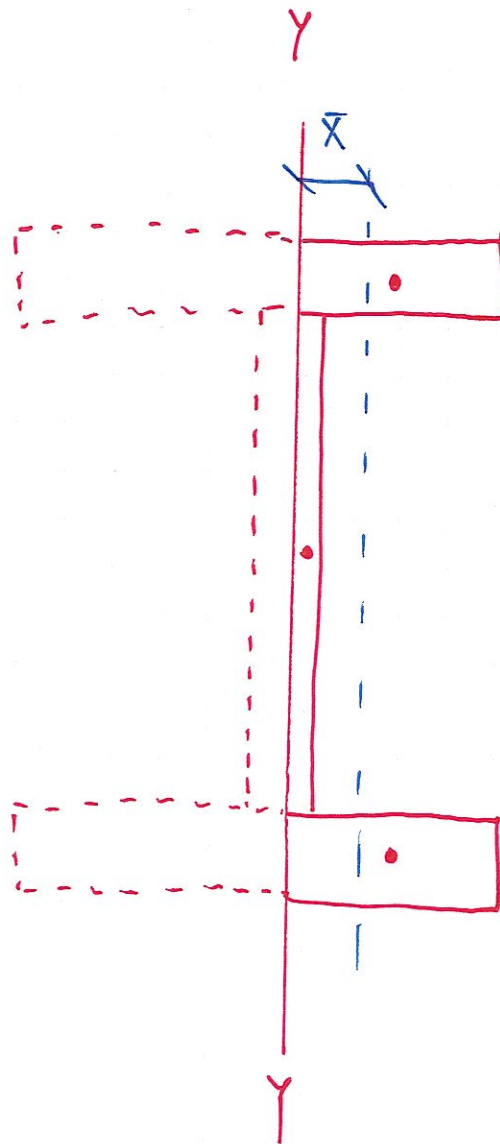
$$(AISC Z_x = 153 \text{ in}^3)$$

$$c) M_y = f_y S_x = (50 \text{ ksi}) (128 \text{ in}^3) \left(\frac{1}{12}\right) = 533 \text{ k-ft} \quad \text{"first yield"}$$

$$d) M_p = f_y Z_x = (50 \text{ ksi}) (150.5 \text{ in}^3) \left(\frac{1}{12}\right) = 627 \text{ k-ft} \quad \text{"Plastic Moment"}$$

$$e) \text{ Shape Factor} = \frac{M_p}{M_y} = \frac{\cancel{f_y} Z_x}{\cancel{f_y} S_x} = \frac{Z_x}{S_x} = \frac{150.5}{128} = 1.17$$

*AISC Man. account for fillets thus I_x, S_x, Z_x are slightly larger
& more accurate



$$q = 2\bar{x}$$