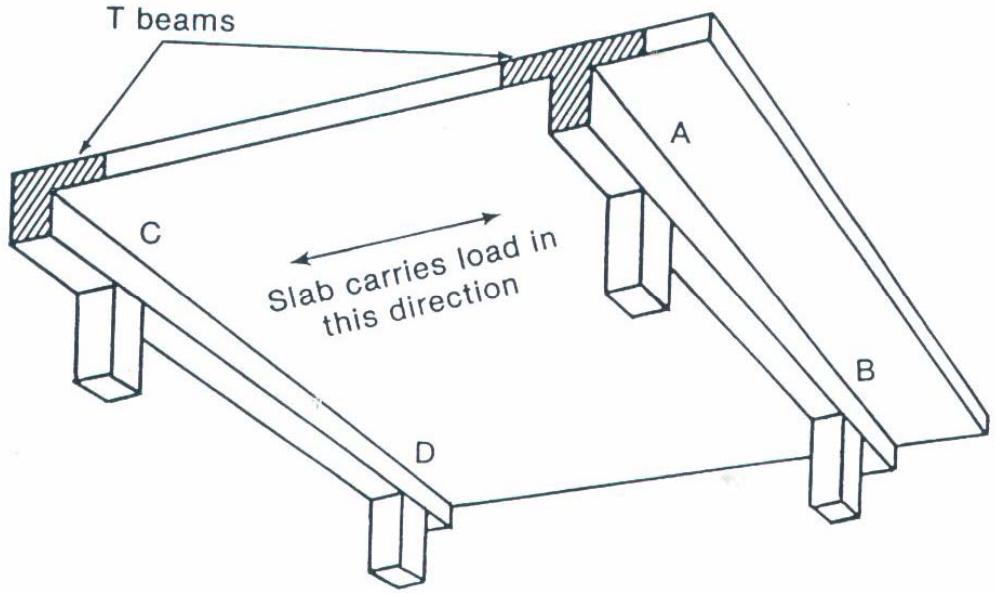
Lecture 11 - Flexure

Lecture Goals

- Basic Concepts
- T Beams and L Beams

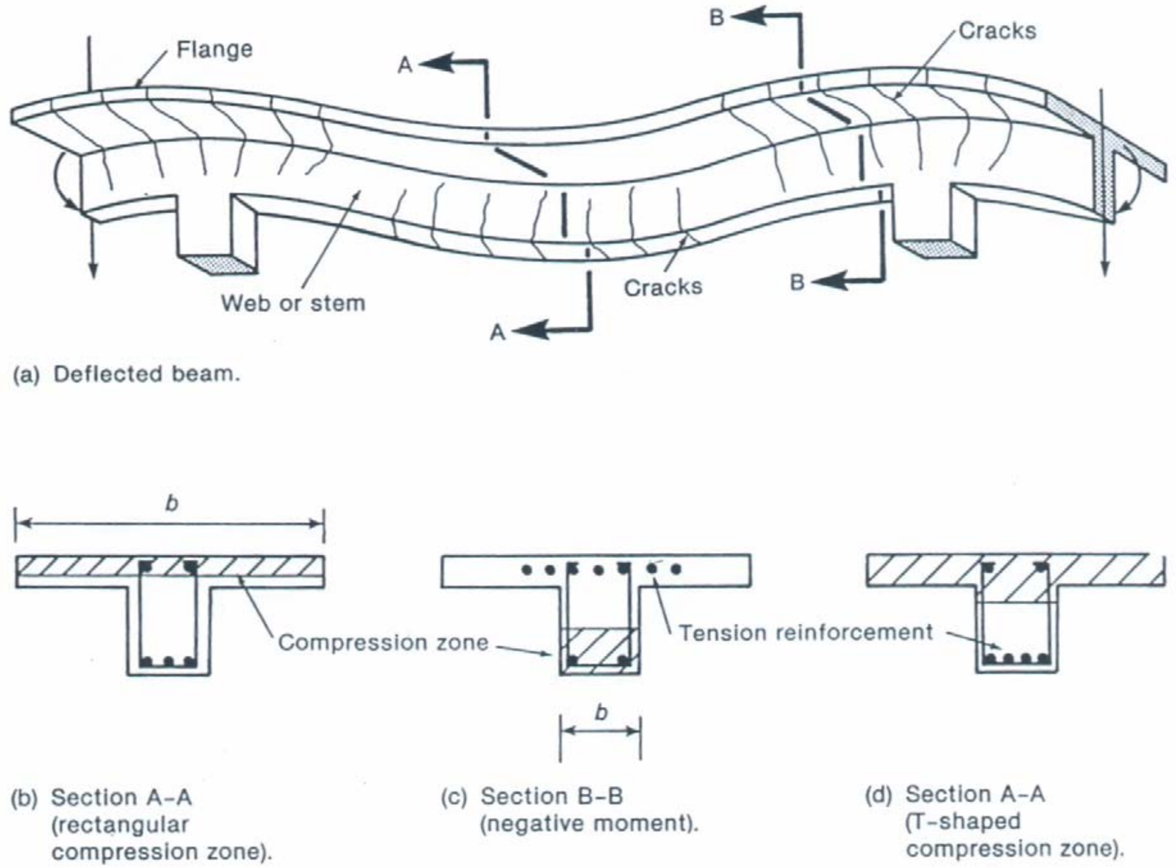
Analysis of Flanged Section

- Floor systems with slabs and beams are placed n monolithic pour.
- Slab acts as a top flange to the beam; ***T-beams***,and ***Inverted L(Spandrel) Beams***.



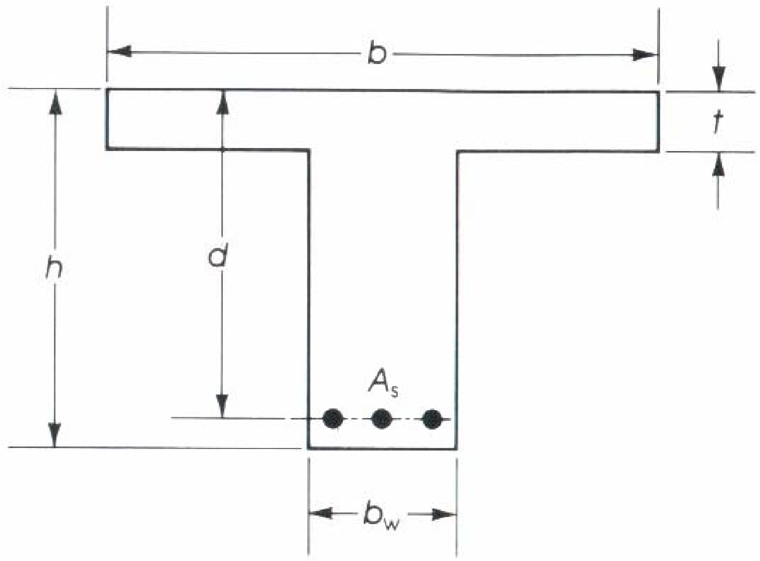
Analysis of Flanged Sections

Positive and Negative Moment Regions in a T-beam



Analysis of Flanged Sections

If the neutral axis falls within the slab depth analyze the beam as a rectangular beam, otherwise as a T-beam.

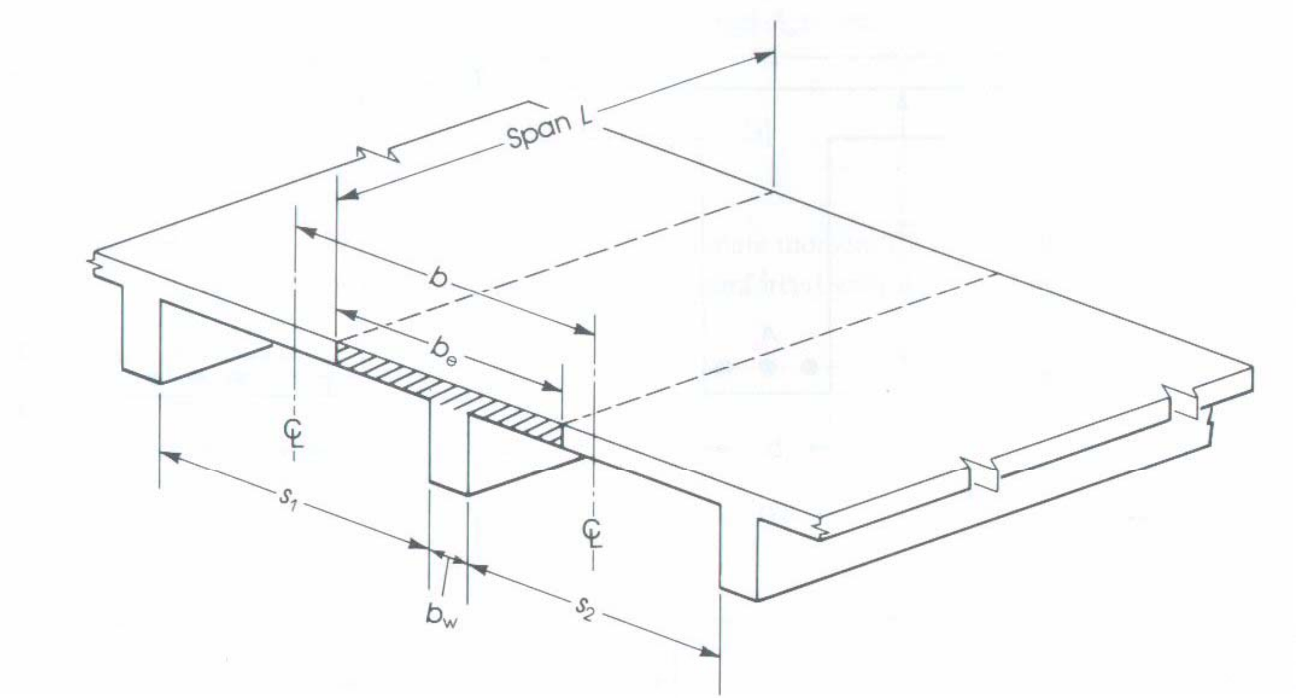


(a)

Analysis of Flanged Sections

Effective Flange Width

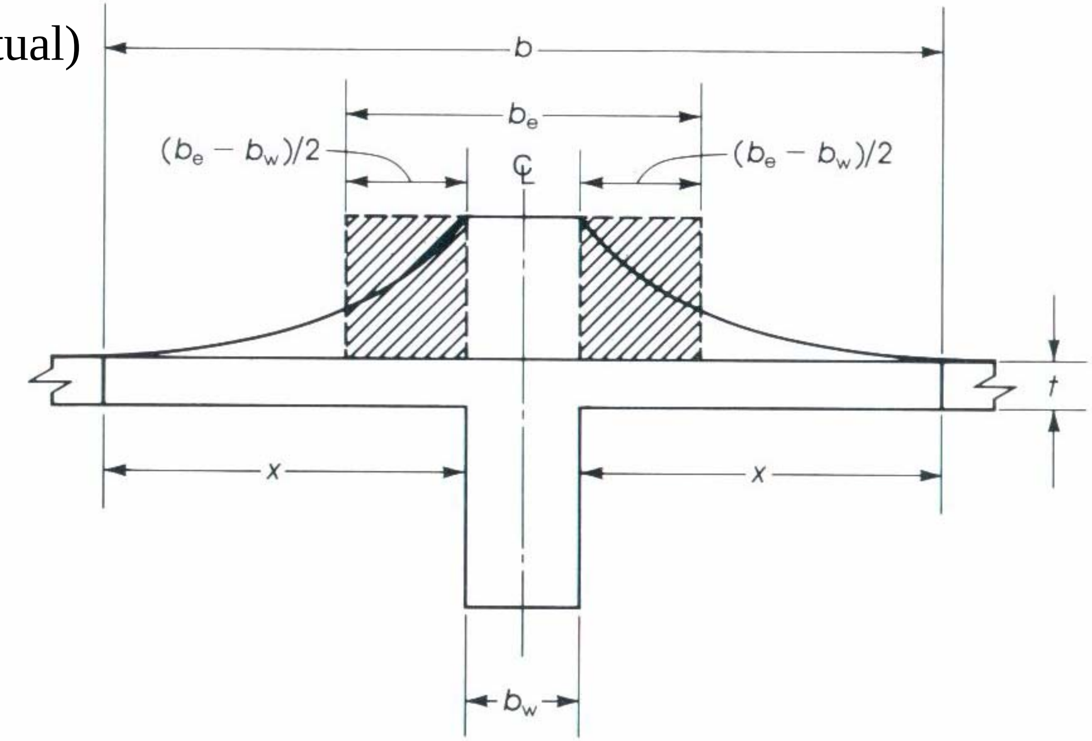
Portions near the webs are more highly stressed than areas away from the web.



Analysis of Flanged Sections

<u>Effective width</u> (b_{eff})

b_{eff} is width that is stressed uniformly to give the same compression force actually developed in compression zone of width $b_{(actual)}$



ACI Code Provisions for Estimating b_{eff}

From ACI 318, Section 8.10.2

T Beam Flange:

$$
\begin{aligned}
b_{\mathrm{eff}} &\le \frac{L}{4} \\
&\le 16h_{\mathrm{f}} + b_{\mathrm{w}} \\
&\le b_{\mathrm{actual}}
\end{aligned}
$$

ACI Code Provisions for Estimating b_{eff}

From ACI 318, Section 8.10.3

Inverted L Shape Flange

$$
\begin{aligned}
b_{\text{eff}} &\le \frac{L}{12} + b_{\text{w}} \\
&\le 6h_{\text{f}} + b_{\text{w}} \\
&\le b_{\text{actual}} = b_{\text{w}} + 0.5*(\text{clear distance to next web})
\end{aligned}
$$

ACI Code Provisions for Estimating b_{eff}

From ACI 318, Section 8.10

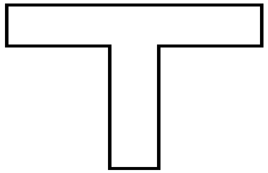
Isolated T-Beams

$$h_f \geq \frac{b_w}{2}$$

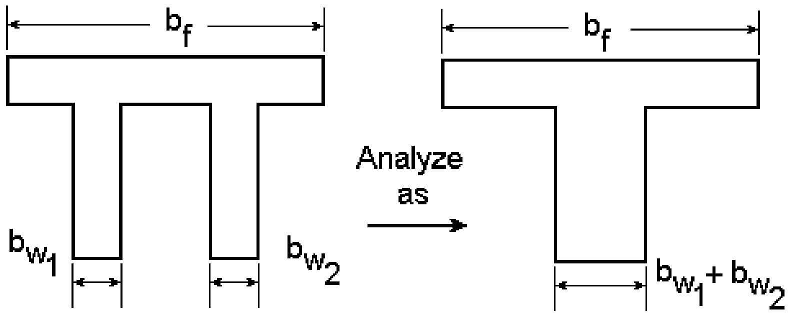
$$b_{eff} \leq 4b_w$$

Various Possible Geometries of T-Beams

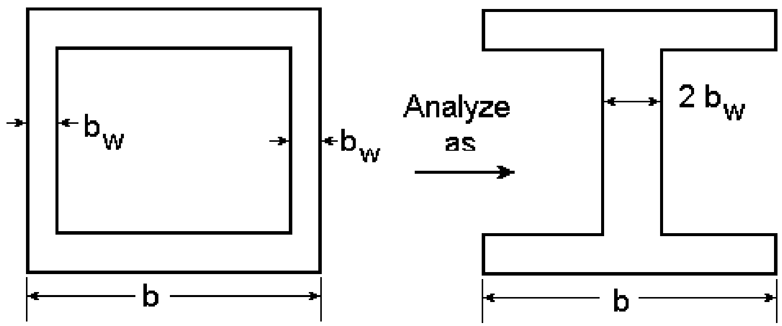
Single Tee



Twin Tee



Box



Analysis of T-Beam

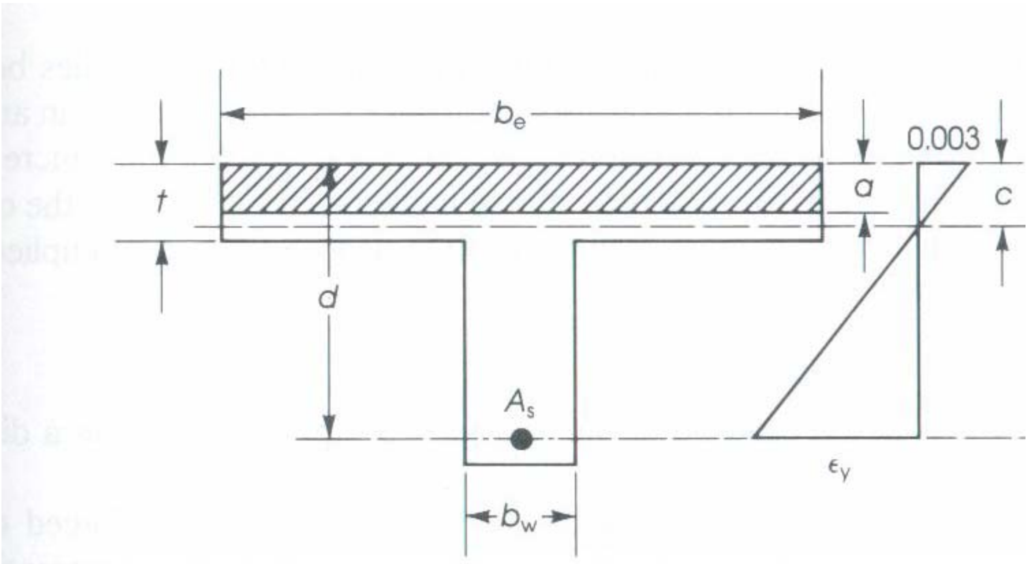
Case 1: $a \le h_f$ Same as rectangular section

Assume $\varepsilon_s \ge \varepsilon_y \Rightarrow f_s = f_y$

Steel is yielding under reinforced

Check

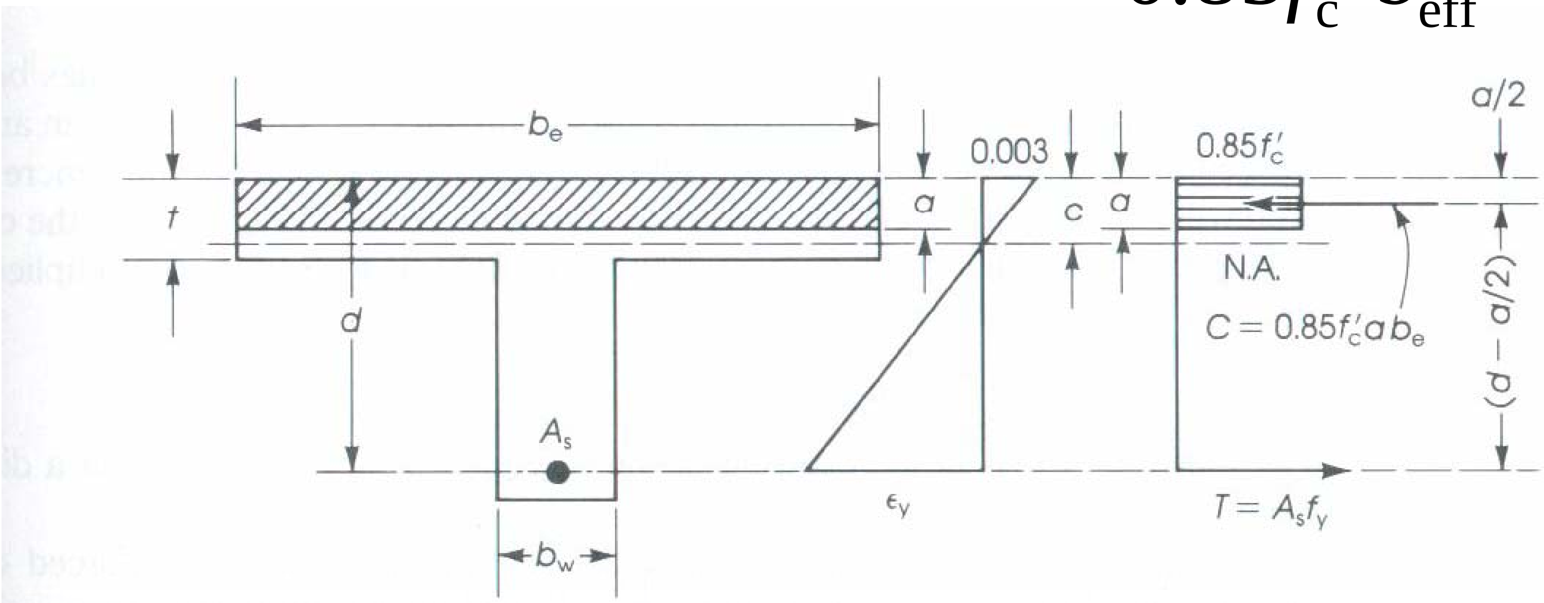
$$a \le h_f$$



Analysis of T-Beam

Case 1: $a \leq h_f$

Equilibrium $$T = C \Rightarrow a = \frac{A_s f_y}{0.85 f_c' \, b_{eff}}$$



Analysis of T-Beam

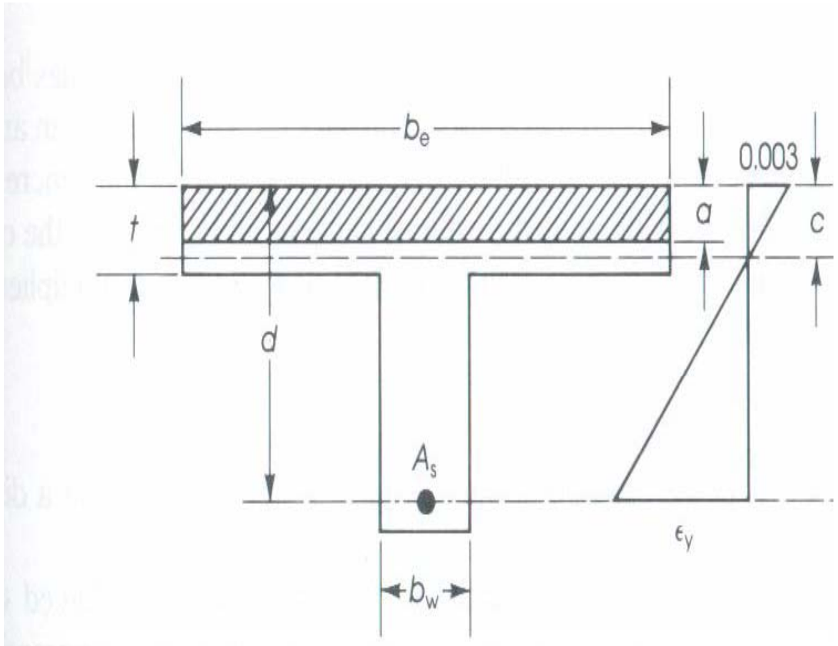
Case 1: $a \le h_f$

Confirm

$$\varepsilon_s \ge \varepsilon_y$$

$$c = \frac{a}{\beta_1}$$

$$\varepsilon_s = \left(\frac{d-c}{c}\right)\varepsilon_{cu} \ge \varepsilon_y$$

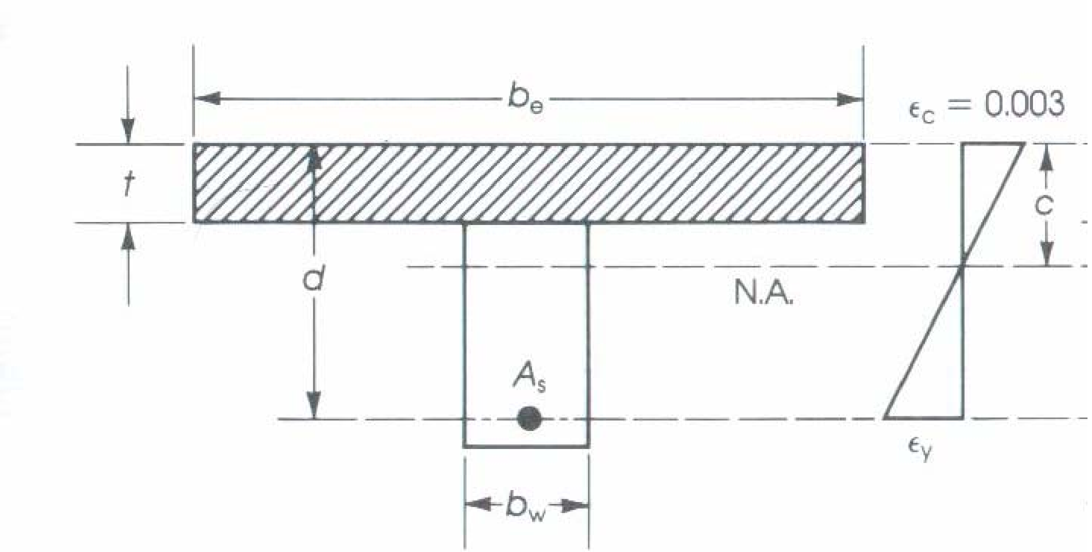


Analysis of T-Beam

<u>Case 1</u>: $a \le h_f$

Calculate M_n

$$M_n = A_s f_y \left(d - \frac{a}{2} \right)$$



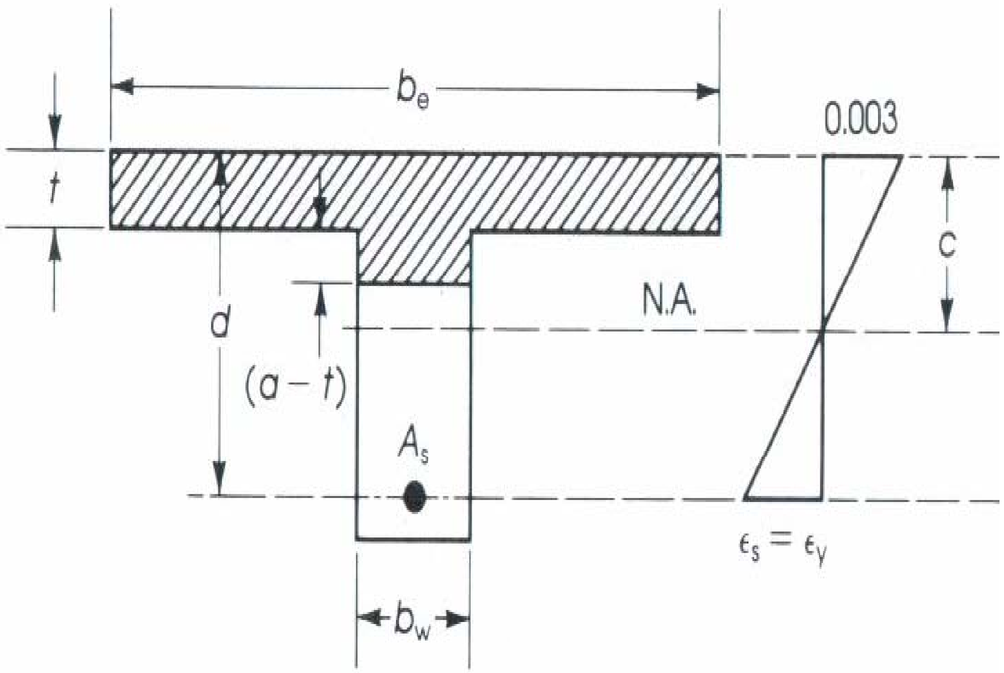
Analysis of T-Beam

Case 2: $a > h_f$ Assume steel yields

$$C_f = 0.85 f_c' (b - b_w) h_f$$

$$C_w = 0.85 f_c' b_w a$$

$$T = A_s f_y$$



Analysis of T-Beam

Case 2: $a > h_f$ Assume steel yields

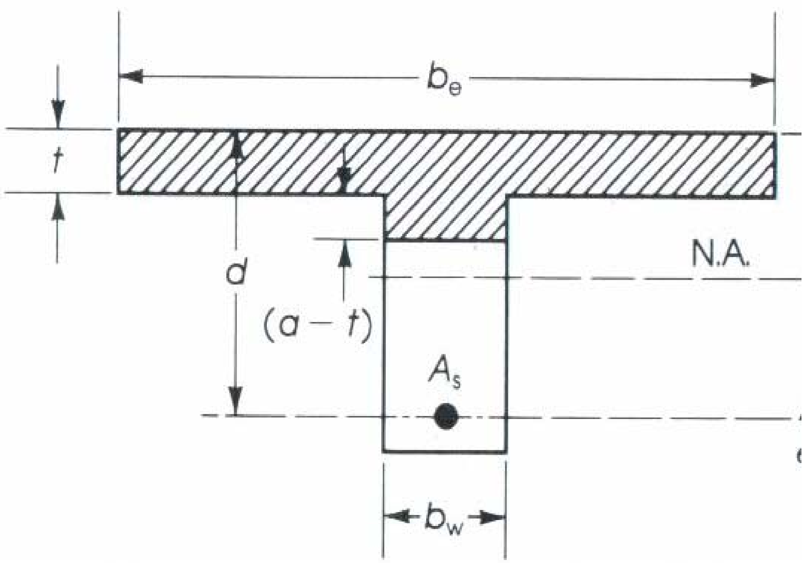
$$A_{sf} = \frac{0.85 f_c' \left(b - b_w \right) h_f}{f_y}$$

The flanges are considered to be equivalent compression steel.

Analysis of T-Beam

Case 2: $a > h_f$ Equilibrium

$$T = C_f + C_w \Rightarrow a = \frac{\left(A_s - A_{sf}\right) f_y}{0.85 f_c' b_w}$$



Analysis of T-Beam

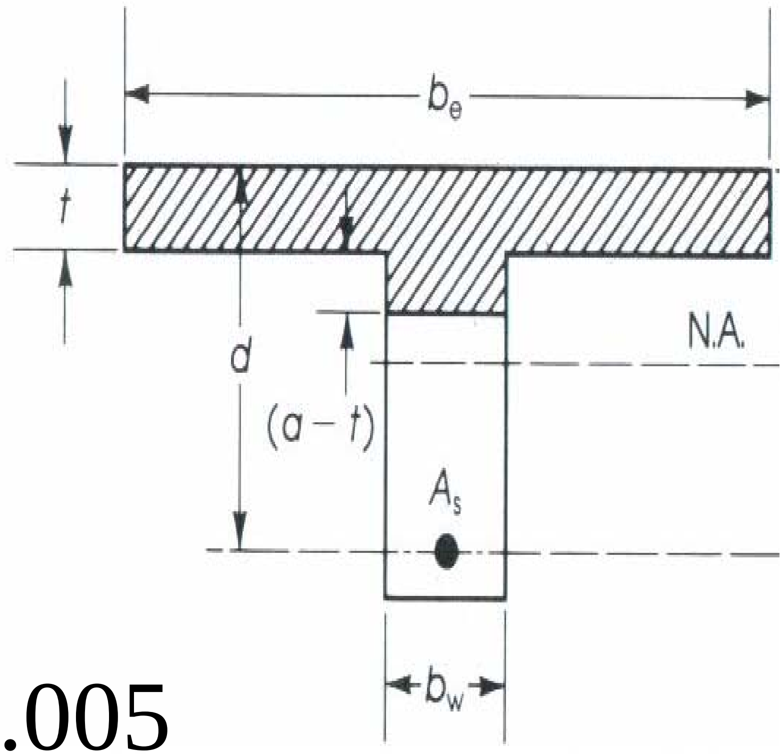
Case 2: $a > h_f$

Confirm

$$a > h_f$$

$$c = \frac{a}{\beta_1}$$

$$\varepsilon_s = \left(\frac{d-c}{c}\right)\varepsilon_{cu} \geq 0.005$$



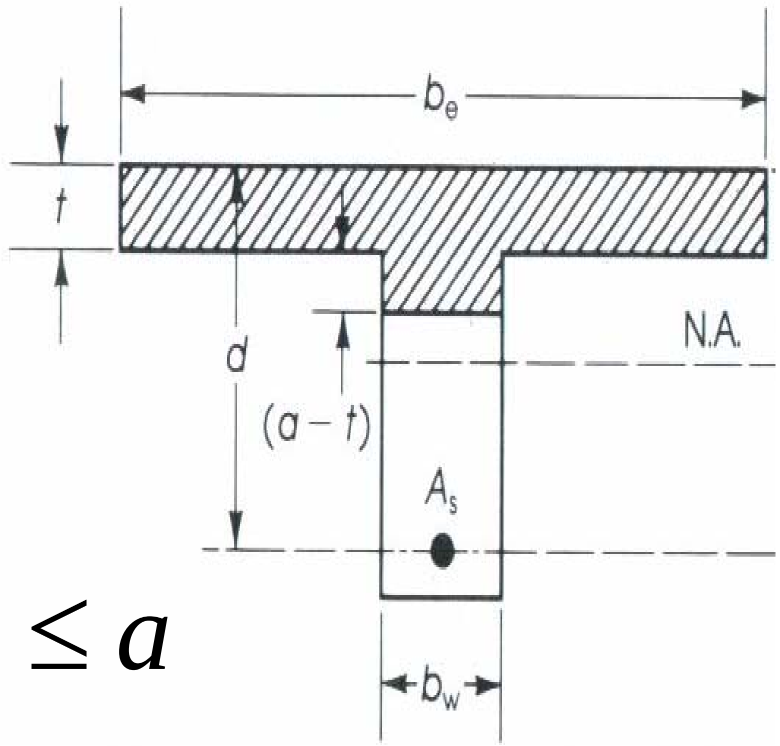
Analysis of T-Beam

Case 2: $a > h_f$

Confirm

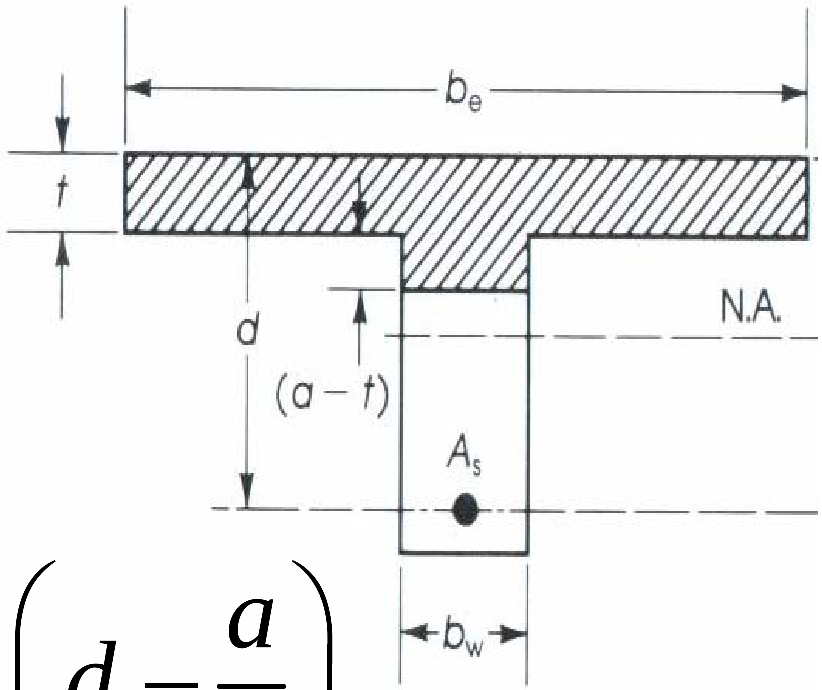
$$\varpi = \rho \frac{f_y}{f_c'}$$

$$h_f \le \frac{1.18\varpi d}{\beta_1} \text{ or } h_f \le a$$



Analysis of T-Beam

Case 2: $a > h_f$



Calculate nominal moments

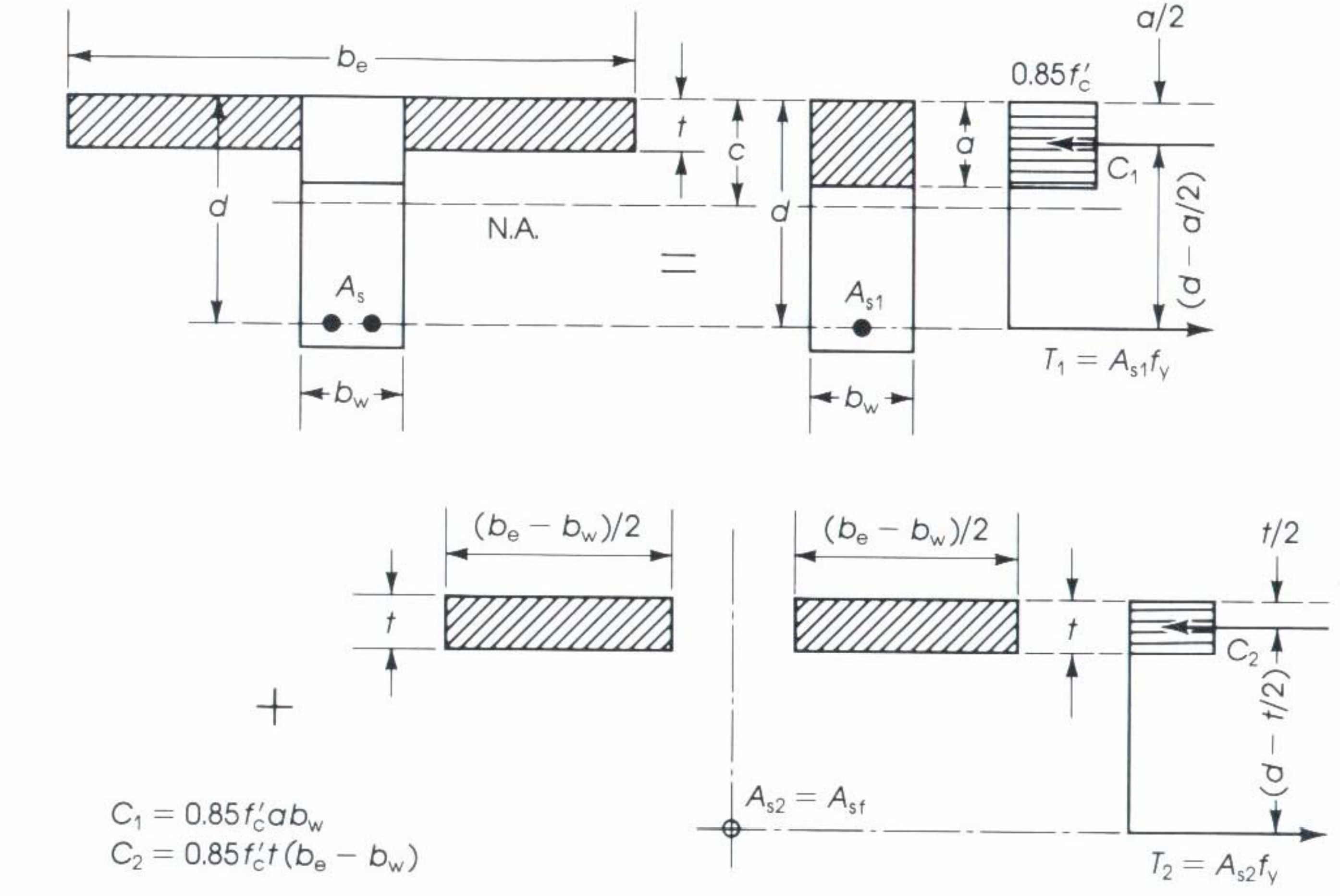
$$M_n = M_{n1} + M_{n2}$$

$$M_{n1} = \left(A_s - A_{sf}\right) f_y \left(d - \frac{a}{2}\right)$$

$$M_{n2} = A_{sf}\, f_y \left(d - \frac{h_f}{2}\right)$$

Analysis of T-Beams

The definition of M_{n1} and M_{n2} for the T-Beam are given as:



Analysis of T-Beams

The ultimate moment M_u for the T-Beam are given as:

$$M_u = \phi M_n$$

$$\phi = 0.9$$

For a T-Beam with the tension steel yielded.

Limitations on Reinforcement for Flange Beams

- Lower Limits
  - Flange in compression

$$\rho_{\text{min}} = \frac{A_{\text{s}}}{b_{\text{w}} d} = \text{ larger of } \begin{cases} \dfrac{3\sqrt{f_{\text{c}}'}}{f_{\text{y}}} \\ \dfrac{200}{f_{\text{y}}} \end{cases}$$