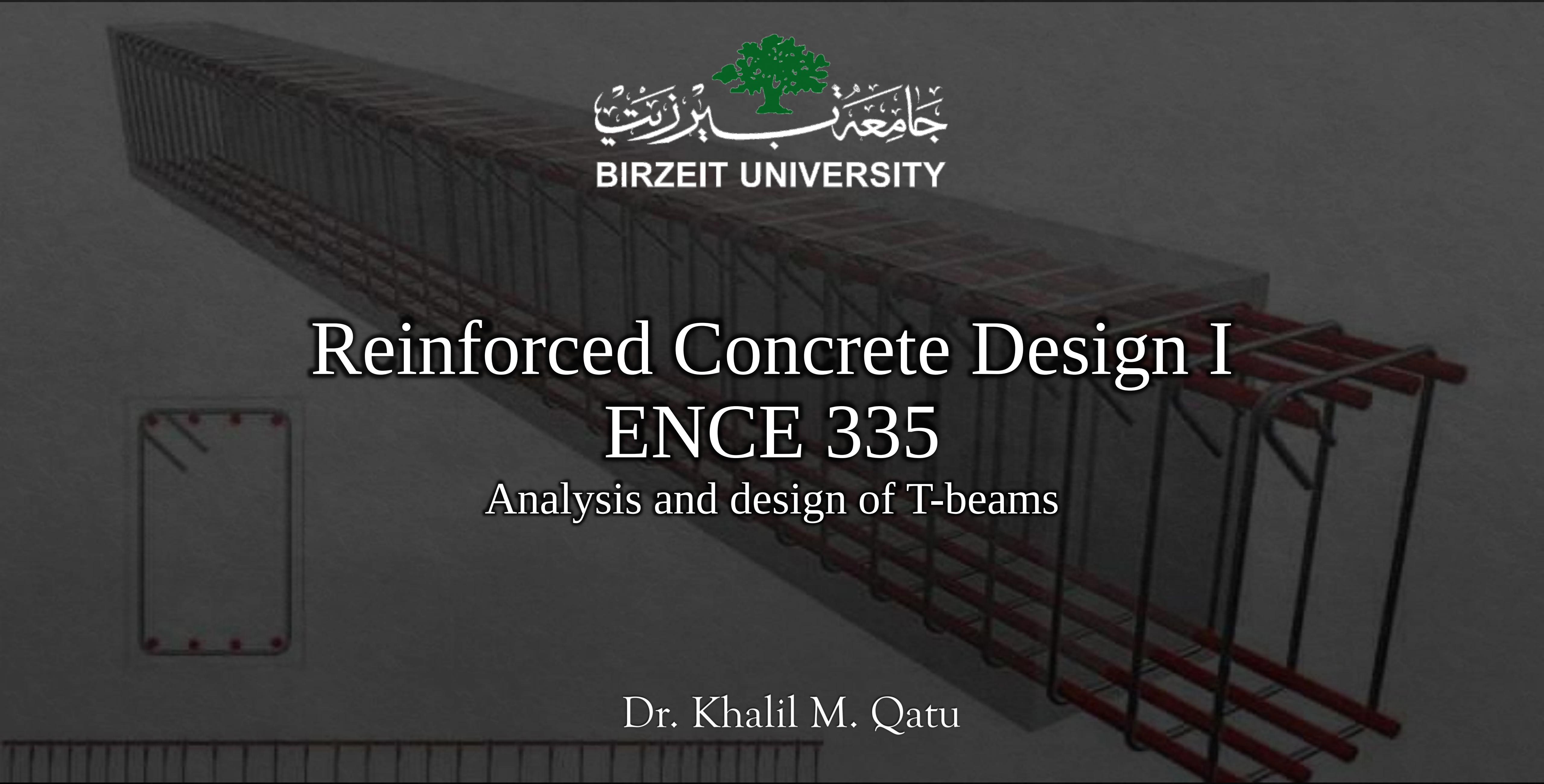


BIRZEIT UNIVERSITY

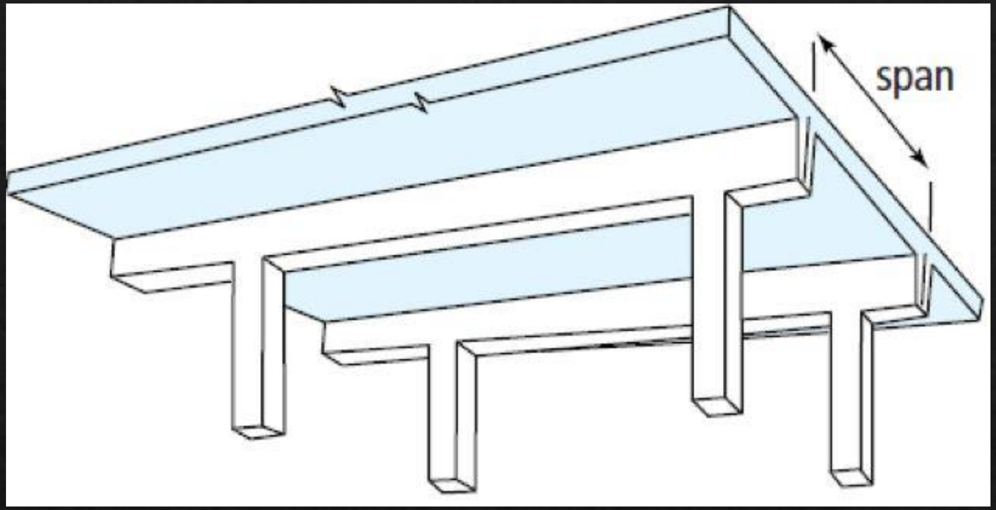
Reinforced Concrete Design I
ENCE 335

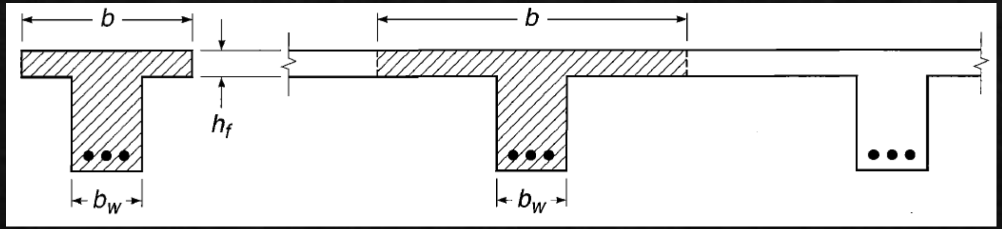
Analysis and design of T-beams

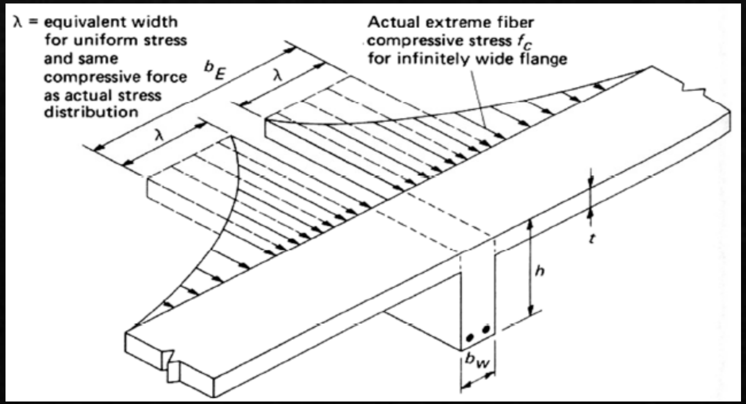
Dr. Khalil M. Qatu

What are T-section beams

- In most cases, Slabs and beams are cast at the same time
- Forms are built for the beams' sides and bottoms as well as the bottom of the slab
- This is called Monolithic construction
- In This case, part of the slab (its transverse direction) will resist comp. forces with the upper part of the beam.
- This part of the slab forms the Flanges of the beam and the drop part of the beam is Stem or Web.
- The resulting cross-section is T-Shaped





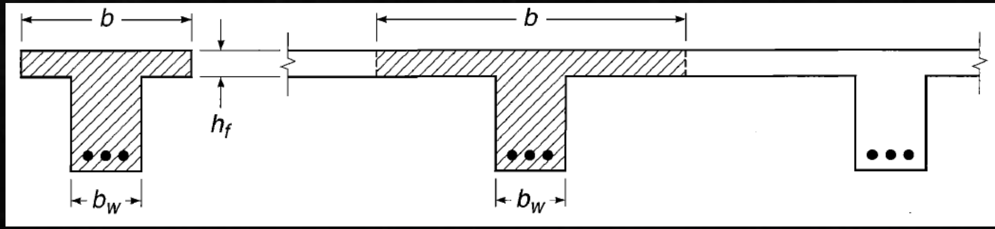


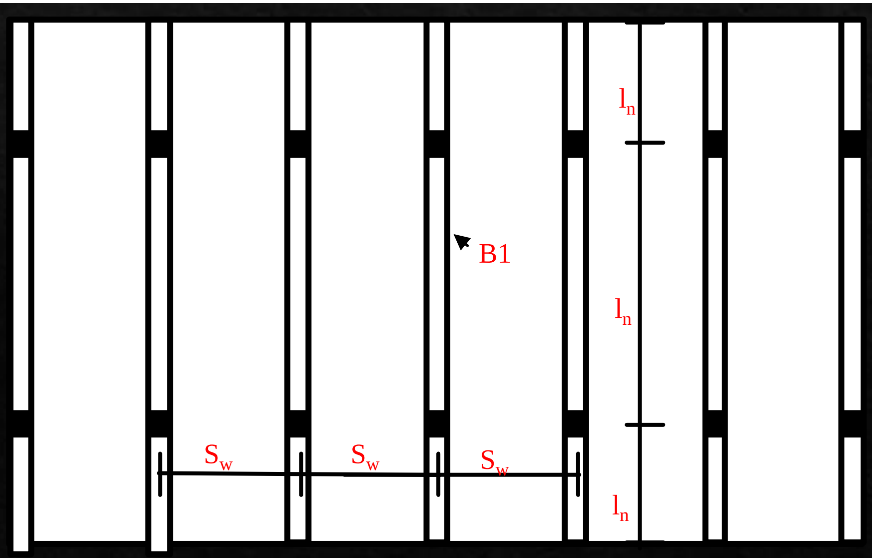
What are T-section beams

- Effective width
  - For non-prestressed T-beams supporting monolithic or composite slabs.
  - The effective flange width b_f shall include the beam web width b_w plus an effective overhanging flange width in accordance with Table 6.3.2.1
  - Where h is the slab thickness and s_w is the clear distance to the adjacent web.

Table 6.3.2.1—Dimensional limits for effective overhanging flange width for T-beams

Flange location	Effective overhanging flange width, beyond face of web	
Each side of web	Least of:	$8h$
		$s_w/2$
		$l_n/8$
One side of web	Least of:	$6h$
		$s_w/2$
		$l_n/12$

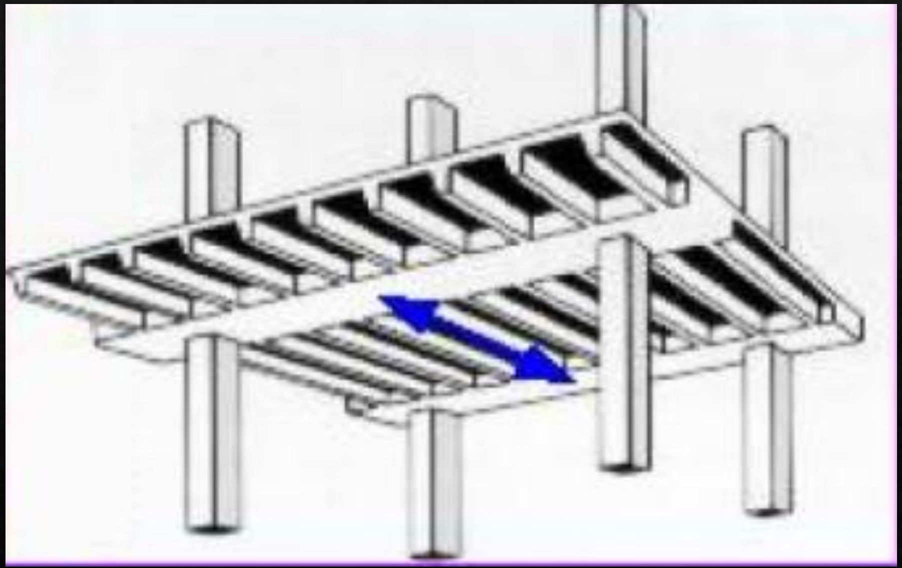


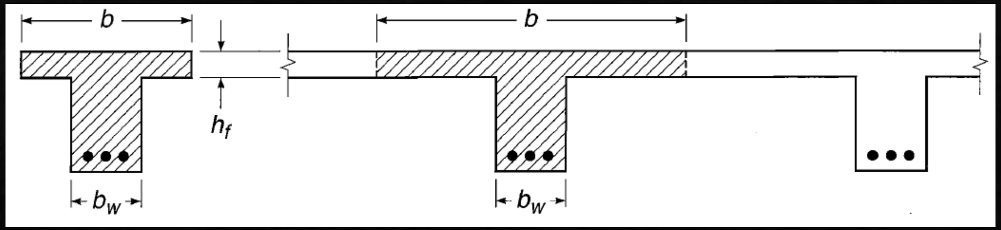


What are T-section beams

- In some cases, engineers choose a T-shaped cross-section to increase the available compression area in the beam.

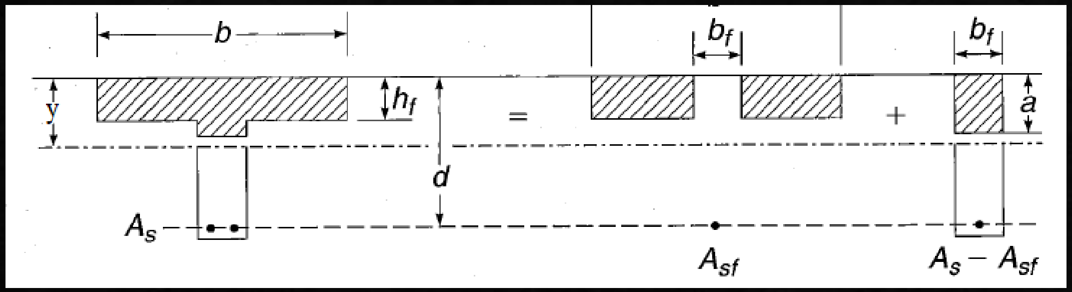
- The ACI code requires :
  - Flange thickness $\geq 0.5b_w$
  - Effective flange width $\leq 4b_w$

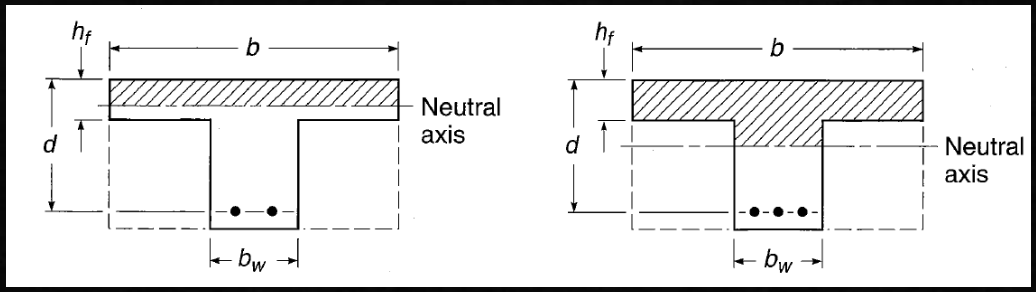




Analysis of T-sections

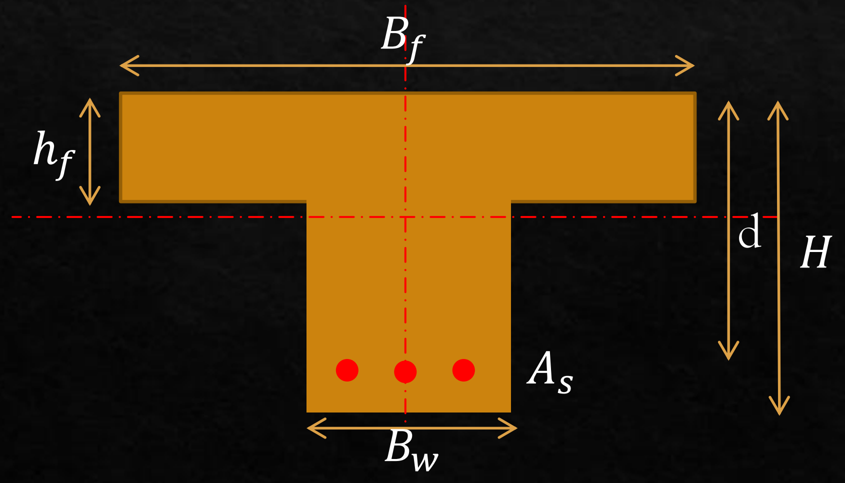
- The N.A. of the beam may lie either in the FLANGE or in the WEB.
- This depends on the section geometry, material properties, and the amount of tensile steel.
- If $N.A. \leq h_f$: the beam can be analyzed as a rectangular section with width B_f and depth H.
  - WHY?
- If $N.A. \geq h_f$: the compression area is divided into two parts
  - The first part is the flange over-hang from each side which is coupled with part of the tension steel (A_{sf})
  - The second Part is the portion of the Web in compression which is coupled with the rest of the tension steel $(A_s - A_{sf})$
- What is the Direction of the moment?? (+ or -)

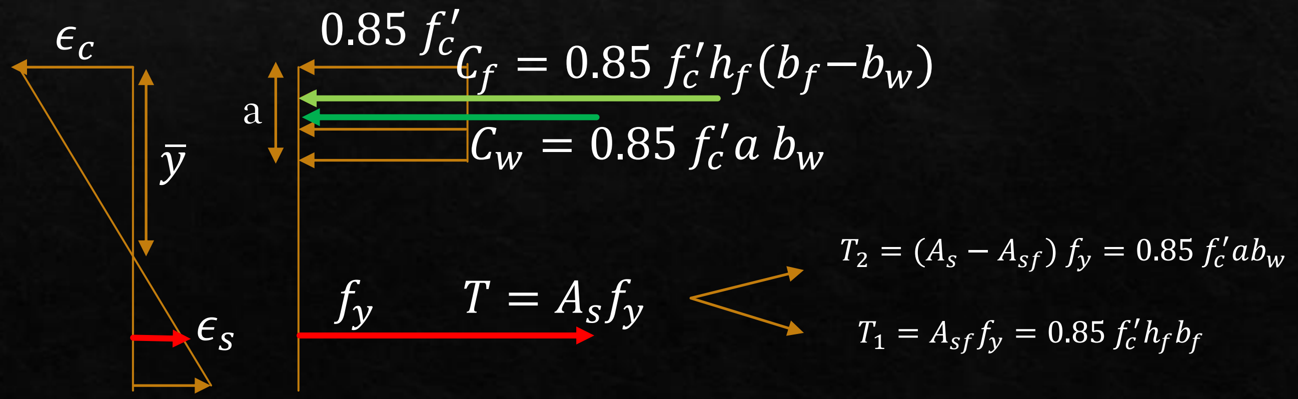




Analysis of T-sections

- Analysis of T-sections → Assuming rect. Section → T=C, $a = \dfrac{A_s f_y}{0.85 f_c' b}$
  - $a \le h_f$ → Analyze as rect. Section → $T = C$, $A_s f_y = 0.85 f_c' a\, b_f$ → $\phi M_n = \phi A_s f_y \left(d - \frac{a}{2}\right)$
  - $a > h_f$ → Analyze as T-section
    - $T_1 = C_f$, $A_{sf} f_y = 0.85\, f_c' h_f (b_f - b_w)$ → $\phi M_{nf} = \phi A_{sf} f_y \left(d - \frac{h_f}{2}\right)$
    - $T_2 = C_w$, $(A_s - A_{sf})\, f_y = 0.85\, f_c' a\, b_w$ → $\phi M_{nw} = \phi (A_s - A_{sf})\, f_y \left(d - \frac{a}{2}\right)$

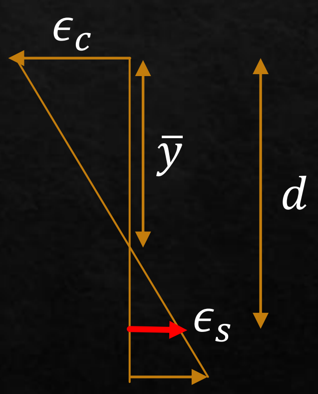




Analysis of T-sections

- Tension Reinforcement limits
  - Minimum reinforcement remains the same ($\rho_w > \rho_{min}$)
  - Maximum reinforcement allowed by ACI code still maintains a tension strain in steel $\epsilon_t \geq 0.004$
    - We can calculate and compare the strain in the tension steel with the limit from the strain distribution

$$\epsilon_s = \epsilon_u \frac{d - \bar{y}}{\bar{y}} \geq 0.004$$



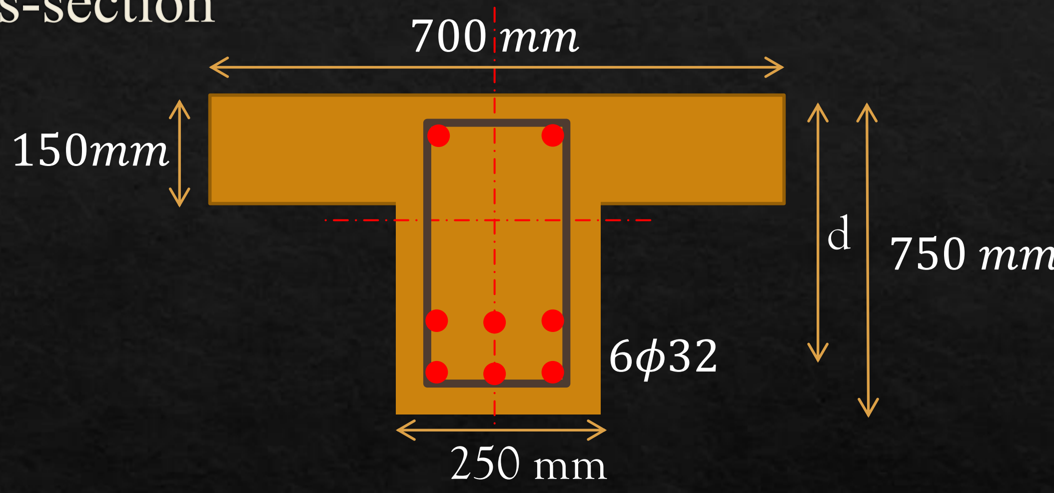
    - Or we can use this formula (derived from strain distribution and section equilibrium)

$$\bar{\rho}_{0.004} = \rho_{0.004} + \rho_f$$

Analysis of T-sections

Example: Calculate the Moment capacity of the given cross-section

$f_y = 420\ MPa\ \ldots\ldots f_c' = 21\ MPa$



Analysis of T-sections

Example: Design

The floor system shown, consists of a 75mm concrete slab supported by continuous beams with 7.5 m span, and 1.2m center to center spacing. The Web dimensions were determined using the negative moment. Design the interior beam B1 indicated below knowing that the ultimate positive moment ($M_u = 750\ kN.m$)

$$f_y = 420\ MPa\ \ldots\ldots f_c' = 21\ MPa$$

$$b_e = min\left\{\begin{array}{c} 2(8h) + b_w = 1475\ mm \\ 2\left(\frac{s_w - b_w}{2}\right) + b_w = 1200\ mm \leftarrow \\ 2\left(\frac{l_n}{8}\right) + b_w = 2150\ mm \end{array}\right\}$$

Table 6.3.2.1—Dimensional limits for effective overhanging flange width for T-beams

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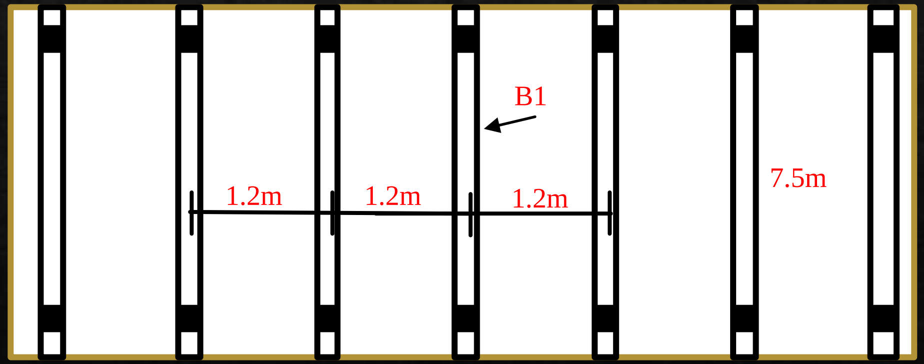

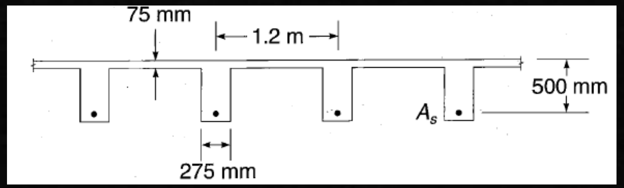

Arbitrary cross-sections