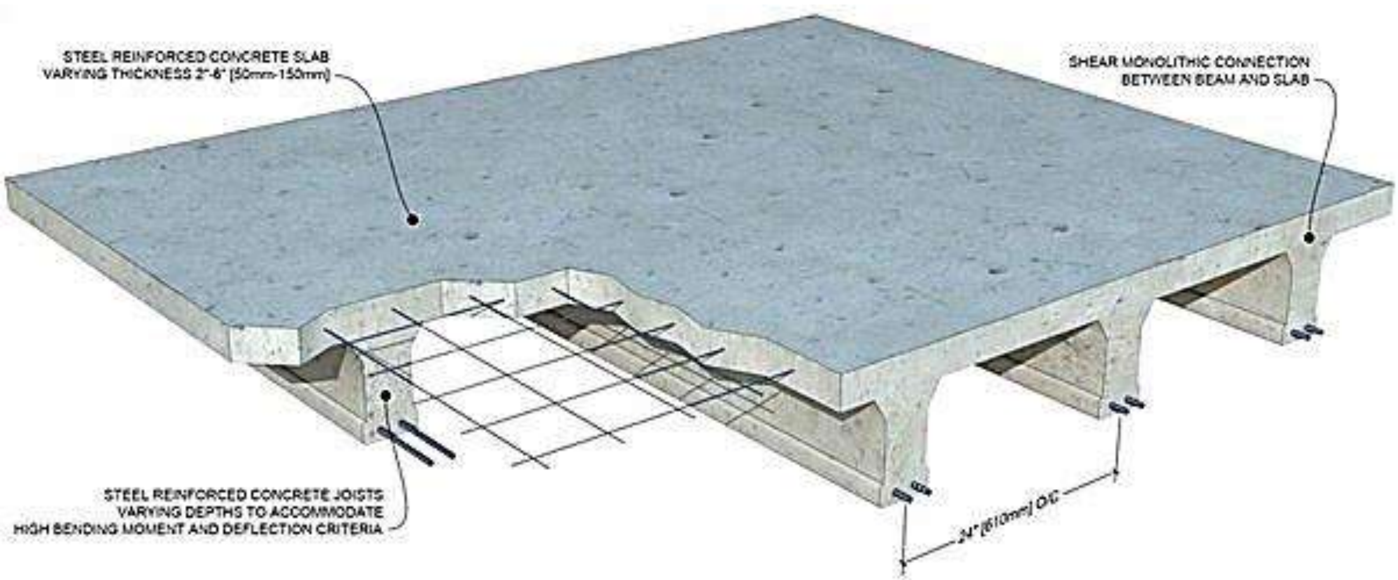
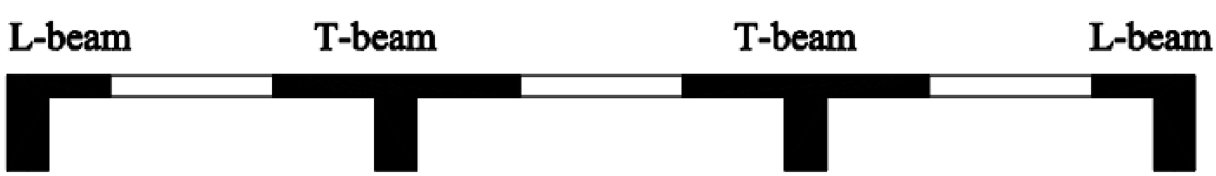
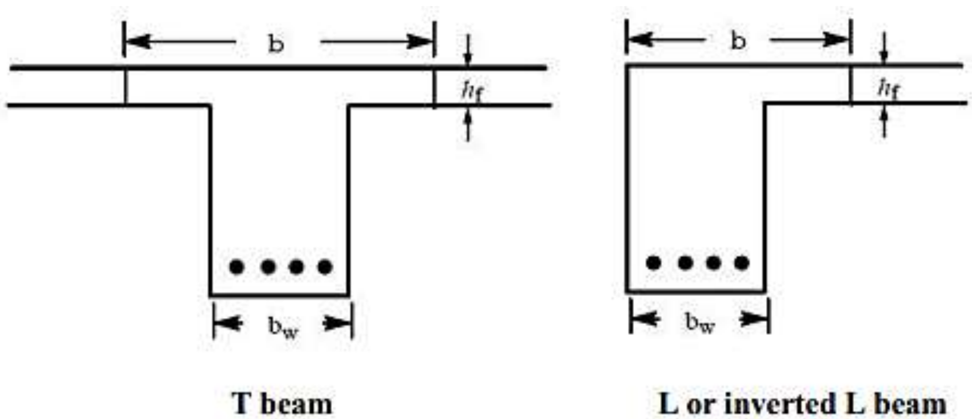
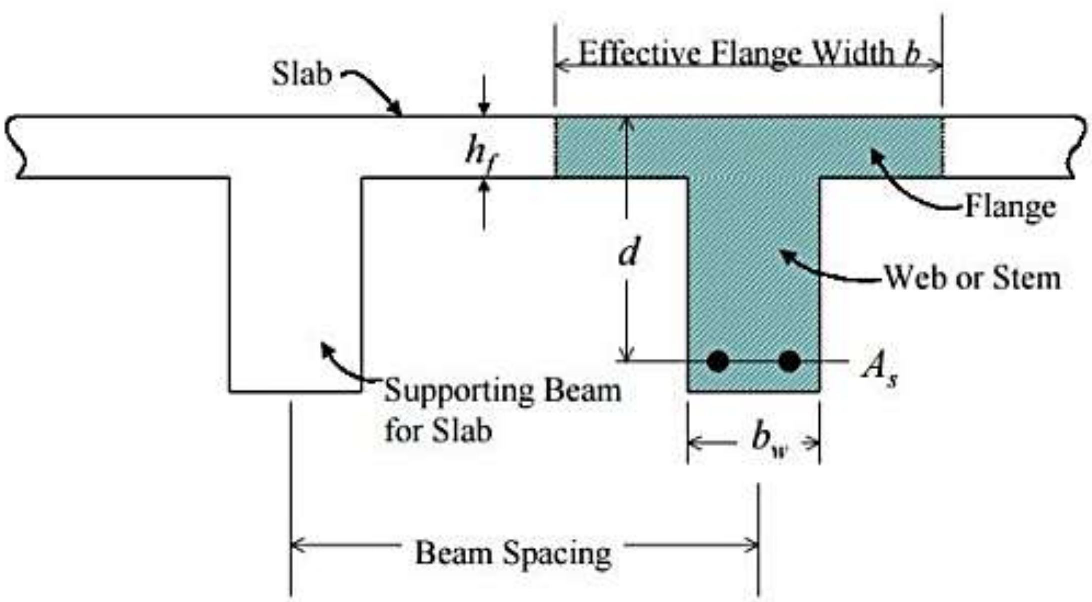
Analysis and Design of T- Beam

When floor slabs and their supporting beams are cast monolithically, they deflect along with the beams under the action of external loads. Therefore, slabs in the vicinity of the beams act as flanges for the beam. Interior beams have a flange on both sides, which are called T-beams. Edge beams have a flange on one side only, and referred to as L-beams as shown in Figure 8. Isolated T-beams, which are produced as precast concrete elements, are used in concrete construction.






b
h_f
b_w
T beam
b
h_f
b_w
L or inverted L beam


Slab
Effective Flange Width b
h_f
Flange
d
Web or Stem
A_s
Supporting Beam
for Slab
b_w
Beam Spacing

Effective width of the flange can be calculated as per ACI 318 section 8.10.2 which is given in the following table:

T-Beam	L-Beam
1. $b \leq \frac{Span}{4}$ 2. $b \leq b_w + 16h_f$ 3. $b \leq$ average clear distance to adjacent webs + bw **The smallest of three values control**	1. $b \leq b_w + \frac{Span}{12}$ 2. $b \leq b_w + 6h_f$ 3. $b \leq b_w + \frac{C/C\ beam\ distance}{2}$ **The smallest of three values control**

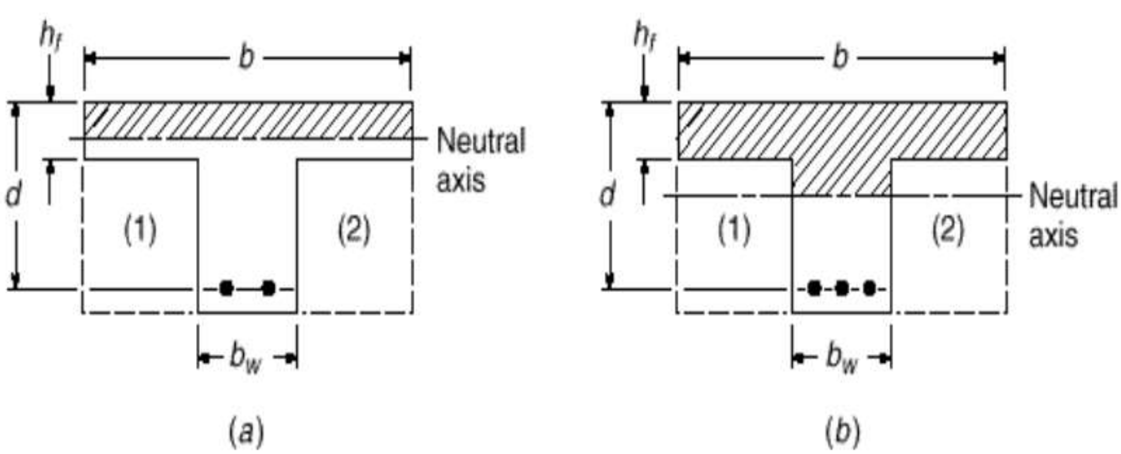
Isolated non pre-stressed T-beams in which the flange is used to provide additional compression area shall have a flange thickness greater than or equal to 0.5bw and an effective flange width less than or equal to 4bw.

$$h_f > \frac{1}{2} * bw \quad and\ bf < 4 * bw$$

<u>Analysis of T or L Beams</u>

The calculation of the design strengths of T beams depend on the neutral axis position,

a- If it falls in the flange then is considered as rectangular sections,
b- While it is T section if the neutral axis is at the web.



Analysis of T-beam

1- Find the depth of compressive area

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

2- If $a \leq h_f$ $\xrightarrow{\text{then}}$ the analysis will be as rectangular beam with (width = b) and (depth = d).

3- If $a > h_f$ $\xrightarrow{\text{then}}$ $A_{sf} = \frac{0.85 f'_c (b - b_w) h_f}{f_y}$

A_{sf}: Area of steel required to equilified the compressive stress of flange

Find ρ_w , $\rho_w = \frac{A_s}{b_w d}$

Find ρ_{wb} , $\rho_{wb} = 0.85 \beta_1 \frac{f'_c}{f_y} \frac{600}{600 + f_y} + \rho_f$

$$\rho_{wb} = \rho_b + \rho_f$$

4- If $\rho_w \leq \rho_{wb}$ $\Longrightarrow$ $a = \frac{A_{sw} f_y}{0.85 f'_c b_w}$

and find M_n from one of the two eqs

$$M_n = M_{n1} + M_{n2} = A_{sf} f_y \left(d - \frac{h_f}{2}\right) + A_{sw} f_y \left(d - \frac{a}{2}\right)$$

or

$$M_n = M_{n1} + M_{n2} = 0.85 f'_c \left[(b - b_w) h_f * \left(d - \frac{h_f}{2}\right) + a \cdot b_w \cdot \left(d - \frac{a}{2}\right)\right]$$

5- If $\rho_w > \rho_{wb}$ then we must calculate (c) by this equation

$$A_s \cdot 600 \cdot \left(\frac{d-c}{c}\right) = 0.85 f'_c (b-b_w) h_f + 0.85 \beta_1 f'_c \, c \, b_w$$

$$a = \beta_1 / c$$

then find M_n:-

$$M_n = 0.85 f'_c (b-b_w) h_f \cdot \left(d - \frac{h_f}{2}\right) + 0.85 f'_c \, a \, b_w \left(d - \frac{a}{2}\right)$$

6- If $\varepsilon_t = 0.005 \xrightarrow{\text{then}} \phi = 0.9$

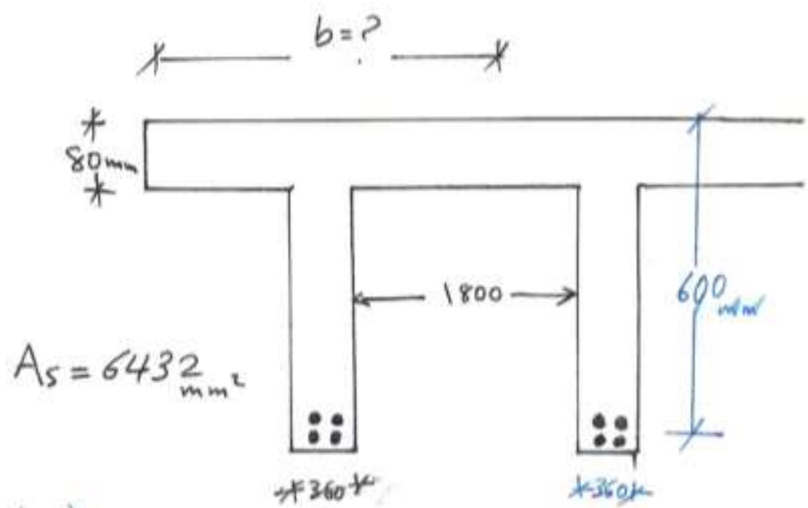
$$\rho_{wt} = 0.85 \beta_1 \frac{f'_c}{f_y} \frac{\varepsilon_u}{\varepsilon_u + 0.005} + \rho_f = \rho_t + \rho_f$$

ρ_{wt} : Reinforcement ratio Caused strain = (0.005) for T-beam

ρ_t : Reinforcement ratio cause strain = (0.005) for rectangular portion

Ex. :- An 80 mm thick continous slab is supported by rectangular beams as shown in the Fig. The span of the beam is 5m, $f'_c = 20.7$ MPa, $f_y = 345$ MPa. Find the design strength of the T-beam

Solution :-



- $b = \frac{L}{4} = \frac{5000}{4} = 1250$ mm
- $b = 16h_f + b_w$

$b = 80 \times 16 + 360 = 1640$ mm

- $b = 360 + 1800$
  $= 2160$ mm

Use $b = 1250$ mm (The smallest value)

- $a = \frac{A_s f_y}{0.85 f'_c b}$

- $a = \frac{A_s f_y}{0.85 * 20.7 * 1250} = \frac{6432 * 345}{0.85 \times 20.7 \times 1250} \Longrightarrow a = 100.9 \text{mm} > 80$ mm

∴ The beam is behaive as T-beam.

$$A_{sf} = \frac{0.85 f'_c (b - b_w) h_f}{f_y} = \frac{0.85 * 20.7 (1250 - 360) \times 80}{345} = 3631 \text{mm}^2$$

$$\therefore \rho_f = \frac{A_{sf}}{b_w d} = \frac{3631}{360 \times 600} = 0.0168$$

$$\rho_b = (0.85)^2 \frac{f'_c}{f_y} \frac{600}{600+f_y} = (0.85)^2 * \frac{20.7}{345} * \frac{600}{600+345} = 0.0289$$

$$\rho_{wb} = \rho_b + \rho_f = 0.0289 + 0.0168 = 0.0457$$

$$\rho_w = \frac{A_s}{b_w d} = \frac{6432}{360 * 600} = 0.0298 < \rho_{wb} = 0.0457$$

$\therefore$ The beam is under reinforced

$$A_{sw} = A_s - A_{sf} = 6432 - 3631 = 2801 \text{ mm}^2$$

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 \times f'_c \times b_w} = \frac{2801 * 345}{0.85 \times 20.7 \times 360} = 152.56 \text{ mm}$$

$$M_u = \phi M_n$$

$$\rho_{wt} = \rho_t + \rho_f = 0.85 \beta_1 \frac{f'_c}{f_y} \frac{\epsilon_u}{\epsilon_u + 0.005} + \rho_f = (0.85)^2 * \frac{20.7}{345} * \frac{0.003}{0.003+0.005} + 0.0168$$

$\because \rho_{wt} > \rho \quad \therefore \phi = 0.9$

$$M_u = \phi \left[A_{sf} f_y \left(d - \frac{h_f}{2}\right) + A_{sw} f_y \left(d - \frac{a}{2}\right) \right]$$

$$M_u = 0.9 \left[3631 \times 345 \left(600 - \frac{80}{2}\right) + 2801 \times 345 \left(600 - \frac{152.56}{2}\right) \right]$$

$$M_u = 1086.8 * 10^6 \text{ N.mm} = 1086.8 \text{ kN.m}$$

H.W: Determine the design strength of the (T beam) shown in Figure below, with f'c'= 25 MPa and fy = 420 MPa. The beam has a (10 m) span and is cast integrally with a floor slab that is (100 mm) thick. The clear distance between webs is (1250 mm).