POSTAL Book Package 2021

CIVIL ENGINEERING

RCC & Prestressed Concrete

Conventional Practice Sets

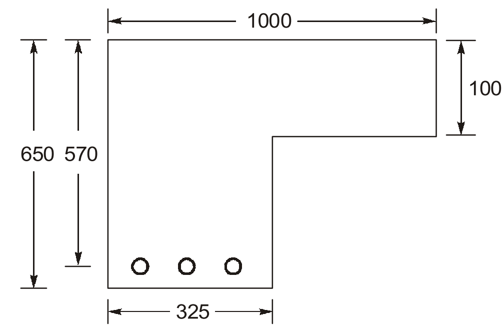
Contents

MADE EASY
Publications

7 CHAPTER

Flanged Beam by LSM

Q.1 The given diagram shows the cross-section at mid-span of a beam at the edge of a slab. A portion of slab in considered as the effective flange width for the beam. The grades of concrete and reinforcing steel are M25 and Fe415 respectively. Total area of reinforcement steel is 4000 mm². Considering the section as under-reinforced and flanged (x_u > 100), calculate depth of neutral axis from top of the flange.



Solution:

Given: $x_u > 100$ mm and section is under-reinforced

$$\boxed{\text{Effective width of flange of } L\text{-beam} = \frac{L_0}{12} + b_w + 3D_f}$$

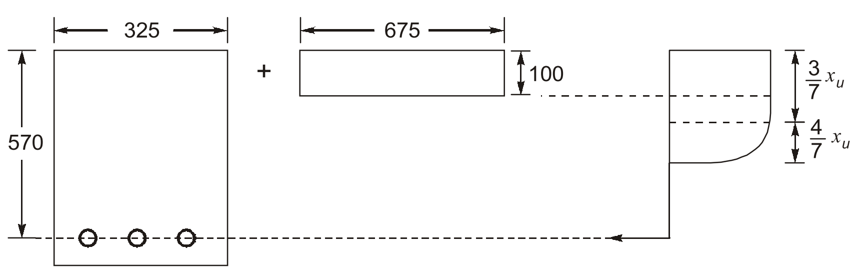
L_0 = distance between point of zero moments

D_f = depth of flange

b_w = width of web

Taking, $b_f = 1000$ mm (∵ length of beam in not given)

Let, $D_f < \frac{3}{7} x_u$



Equating compressive and tensile forces,

$$C = T$$

$$\boxed{0.36 f_{ck} x_u b_w + (100 - b_w) D_f \times 0.45 f_{ck} = 0.87 f_y A_{st}}$$

$$(0.36 \times 25 \times x_u \times 325) + (675 \times 100 \times 0.45 \times 25) = 0.87 \times 415 \times 4000$$

∴ $x_u = 234.13$ mm

Check: $\frac{3}{7} x_u = 100.34 > D_f$

Hence, our assumption was correct.

∴ $x_u = 234.13$ mm

Q.2 Calculate the ultimate flexural strength of T-beam section having the following sectional properties:

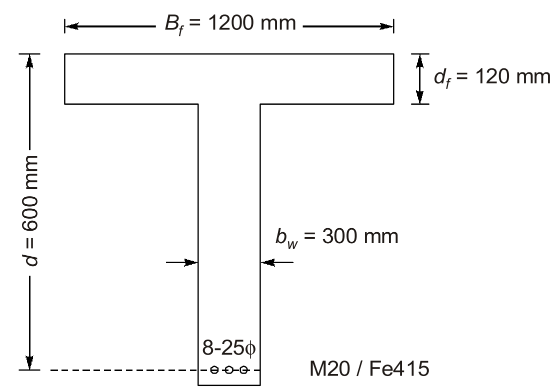
Width of the flange = 1200 mm
Depth of the flange = 120 mm
Width of the rib = 300 mm
Effective depth = 600 mm
Area of tensile steel = 8 bars of 25 mm diameter

Materials : M 20 grade concrete and Fe 415 HYSD bars.

Solution:

From limit state method:

Step-1: Limiting depth of N.A.



For Fe 415, $x_{u,\lim} = 0.48\,d$

$$= 0.48 \times 600$$

$$= 288 \text{ mm}$$

Step-2: Actual depth of N.A.

$$A_{st} = \left(\frac{\pi}{4} \times 25^2\right) \times 8$$

$$= 3927 \text{ mm}^2$$

Case-2.1 : Assume $x_u < d_f = 120$ mm

$$C = T$$

$\Rightarrow$ $0.36 \times f_{ck}\, B_f x_u = 0.87\ f_y\, A_{st}$

$\Rightarrow$ $x_u = \dfrac{0.87 \times 415 \times 3927}{0.36 \times 20 \times 1200} = 164.10 \text{ mm} > d_f$ (Not OK)

Case-2.2: Again assume $x_u > d_f$ and $\frac{3}{7} x_u > d_f$

$$C = T$$

$\Rightarrow 0.45\ f_{ck}\,(B_f - b_w) \times D_f + 0.36\ f_{ck}\ b_w\, x_u = 0.87\ d_f \times A_{st}$

$\Rightarrow 0.45 \times 20\ (1200 - 300) \times 120 + 0.36 \times 20 \times 300\ x_u = 0.87 \times 415 \times 3927$

$$x_u = 206.41 \text{ mm}$$

$\frac{3}{7} x_u = 88.46 \text{ mm} < d_f$ (Not OK)

$\therefore$ $x_u < x_{u,\lim} \Rightarrow$ under reinforced section

Step-3: Calculation for Moment of Resistance

$$\text{MOR} = 0.36 f_{ck} b_w x_u \left(d - 0.42 x_u\right) + 0.45 f_{ck} \times \left(b_f - b_w\right) y_f \left(d - \frac{y_f}{2}\right)$$

$$y_f = 0.15 \times 232.9 + 0.65 \times 120$$

$$= 112.935 \text{ mm}$$

$$\text{MOR} = 0.36 \times 20 \times 300 \times 232.9 \times (600 - 0.42 \times 232.9) + 0.45 \times 20 \times (1200 - 300) \times 112.935 \times \left(600 - \frac{112.935}{2}\right)$$

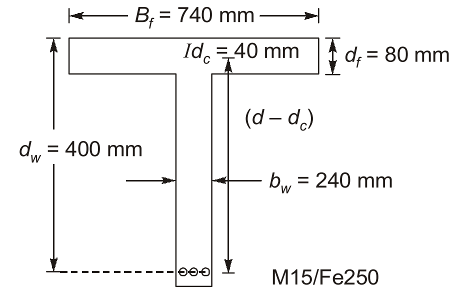
$$\text{MOR} = 749.84 \text{ kNm}$$

Q.3 A T-beam has flange width of 740 mm, flange thickness of 80 mm, web thickness of 240 mm and effective depth of 400 mm. Find area of steel for the applied ultimate moment is 186 kNm. Take f_{ck} = 15 MPa and f_y = 250 N/mm².

Solution:

Applied ultimate moment, $M_u = 186$ kNm

From LSM



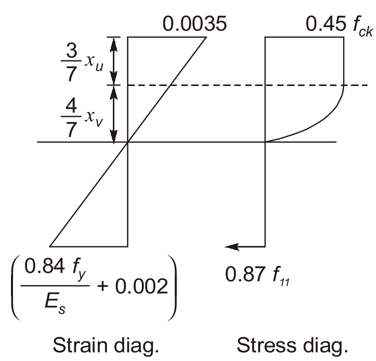
Step-1: Check $x_{u\ lim}$ with Depth of Flange

For balanced section

$$x_u, \text{lim} = 0.53\, d$$
$$= 0.53 \times 400 = 212 \text{ mm}$$
$$\frac{3}{7}x_{u\text{lim}} = \frac{3}{7} \times 212$$
$$= 90.86 \text{ mm} > D_f = 80 \text{ mm}$$

Step-2: Compare M_{ulim} with Applied Ultimate Moment

∴ Ultimate BM capacity for balanced section,



$$\boxed{M_{u,\text{lim}} = 0.3bf_{ck}b_w x_{v\text{lim}}(d - 0.42x_{u\text{lim}}) + 0.45f_{ck}(B_f - b_w) \times D_f(d - 0.5I_f)}$$

$$= 0.36 \times 15 \times 240 \times 212\,(400 - 0.42 \times 212) + 0.45 \times 15(740 - 240) \times 80\,(400 - 0.5 \times 80)$$
$$= 182.64 \times 10^6 \text{ N-mm} = 182.64 \text{ kNm} < M_u$$
$$= \text{design for doubly reinforced section}$$

Step-3: Area of steel in tension

$$\boxed{A_{st} = \frac{0.36f_{ck}b_w x_{u\,\text{lim}}}{0.87\,f_y} + \frac{0.45f_{ck}(B_f - b_w)D_f}{0.87f_y} + \frac{(M_u - M_{u\,\text{lim}})}{0.87f_y(d - d_c)}}$$

$$= \frac{0.36 \times 15 \times 240 \times 212}{0.87 \times 250} + \frac{0.45 \times 15(740 - 240) \times 80}{0.87 \times 250}$$
$$+ \frac{(186 - 182.64) \times 10^6}{0.87 \times 250(400 - 40)} = 2550 \text{ mm}^2$$

Provide 5 – 25 ϕ + 1 – 20 ϕ reinforcement at bottom (A_{st} = 2770 mm^2)

Step-4: Compression Reinforcement,

$$\boxed{A_{sc} = \frac{M_u - M_{u\,\text{lim}}}{f_{sc}(d - d_c)}}$$

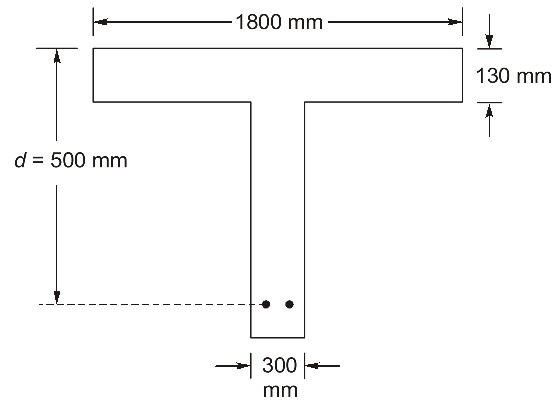
$$= \frac{(186 - 182.46) \times 10^6}{0.87 \times 250(400 - 40)}$$

Assume $f_{sc} = 0.87\ f_y$

$$= 45 \text{ mm}^2$$

∴ Provide 1-12 mm bar at top.

Q.4 Determine limiting moment of resistance and maximum percentage of steel required for the concrete cross-section shown in figure below. Use limit state method, and M15 and Fe415 steel.



Solution:

Given: $B_f = 1800$ mm, $d_f = 130$ mm, $d = 500$ mm, $b_w = 300$ mm

Step-1: Compare $x_{u\,lim}$ with Depth of Flange

$$\text{Limiting depth of neutral axis} = 0.48\,d$$

$$x_{u,\,lim} = 0.48 \times 500 = 240 \text{ mm} > d_f$$

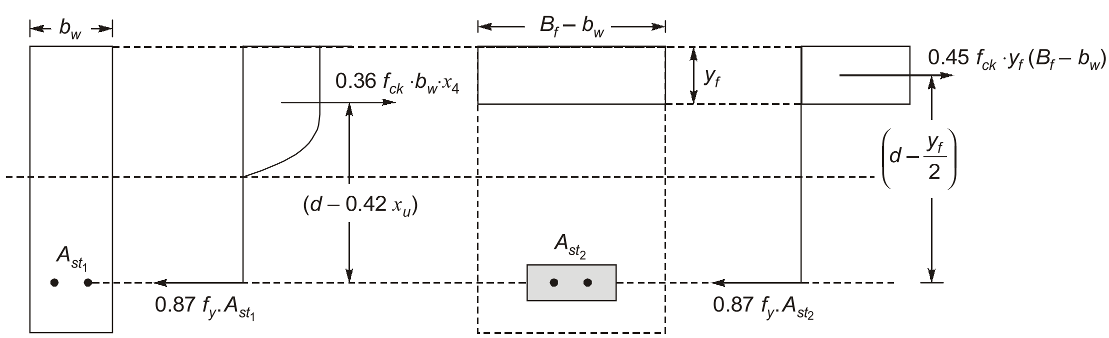
$$\frac{3}{7}x_{u,\,lim} = \frac{3}{7} \times 240 = 102.857 < d_f$$

∴ Let us consider equivalent depth of flange section,

$$y_f = (0.15\,x_u + 0.65\,d_f) \not> d_f$$

$$= 0.15 \times 240 + 0.65 \times 130$$

$$= 120.5 \text{ mm}$$



Step-2: Calculating $M_{u\,lim}$

Moment of resistance of limiting section be $M_{u,\,lim}$,

$$\boxed{M_{u,lim} = \left[0.36 f_{ck}.b_w.x_{u,lim}(d - 0.42)x_{u,lim}\right] + \left[0.45 f_{ck}.y_f.(B_f - b_w) \times \left(d - \frac{y_f}{2}\right)\right]}$$

$$= [0.36 \times 15 \times 300 \times 240 \times (500 - 0.42 \times 240)] +$$

$$[0.45 \times 15 \times 120.5 \times (1800 - 300) \times \left(500 - \frac{120.5}{5}\right)]$$

$$= (155208960 + 536522484.4) \text{ N-mm}$$

$$= 691731444.4 \text{ N-mm}$$

$$= 691.73 \text{ kNm}$$

Step-3: Calculation for Tensile Steel

$$\boxed{A_{st_1} = \frac{0.36 f_{ck}.b_w.x_u}{0.87\, f_y}}$$

$$= \frac{0.36 \times 15 \times 300 \times 240}{0.87 \times 415}$$

$$= 1076.8591 \text{ mm}^2$$

$$\boxed{A_{st_2} = \frac{0.45 f_{ck}.y_f.(B_f - b_w)}{0.87\, f_y}}$$

$$= \frac{0.45 \times 15 \times 120.5 \times 1500}{0.87 \times 415}$$

$$= 3379.2065 \text{ mm}^2$$

$$\text{Total Reinforcement} = A_{st_1} + A_{st_2} = 4456.0656 \text{ mm}^2$$

$$\boxed{\text{Limiting percentage of steel} = \frac{A_{st}}{(B_f \times d_f) + \{b_w \times (d - d_f)\}} \times 100}$$

$$p_t\% = \frac{4456.0656}{(1800 \times 130) + \{300 \times (500 - 130)\}} \times 100$$

$$p_t\% = 1.2916\%$$

Q.5 A simply supported T-beam of span 9 m of reinforced concrete has the following dimensions:

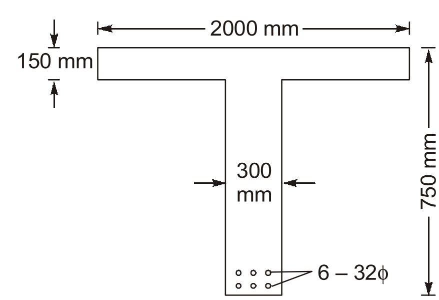
Flange width = 2000 mm
Flange thickness = 150 mm
Overall depth = 750 mm
Rib width = 300 mm

The beam is provided with 6 No. 32 mm diameter HYSD bars of grade Fe 500.
Concrete used is of grade M 25.
Find the moment of resistance of the beam using limit state method.
Also find the magnitude of two point loads at 3 m distance from the ends.

Solution:

Given: Flange width, b = 2000 mm; Span, l_0 = 9 m = 9000 mm; Flange thickness, D_f = 150 mm; Overall depth, D = 750 mm; Rib width, b_w = 300 mm

$$A_{st} = 6 \times \frac{\pi}{4} \times 32^2 = 4825.486 \text{ mm}^2$$



Step-1: Calculate Effective Width

Effective width of flange for an isolated T-beam is given as

$$\boxed{b_f = \frac{l_0}{\left(\frac{l_0}{b}\right) + 4} + b_w}$$

$$= \frac{9000}{\frac{9000}{2000} + 4} + 300$$

$$\Rightarrow \quad b_f = 1358.82 \text{ mm} < b$$