Design of Flanged Sections:

$$b_e = min\begin{cases} b_w + 16h_f \\ b_w + s_w \\ b_w + \frac{l_n}{4} \end{cases} \rightarrow Effective\ Flange\ width\ for\ T-section, SBC304-18, 6.3.2.1$$

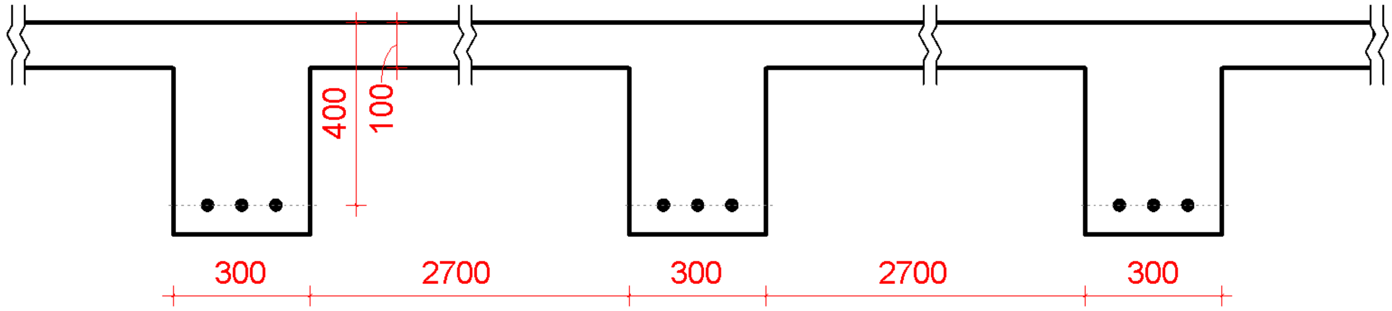
$$b_e = min\begin{cases} b_w + 6h_f \\ b_w + \frac{s_w}{2} \\ b_w + \frac{l_n}{12} \end{cases} \rightarrow Effective\ Flange\ width\ for\ L-section, SBC304-18, 6.3.2.1$$

$$h_f \geq \frac{b_w}{2} \quad b_e \leq 4b_w \rightarrow T\ section\ dimensions\ limitations, SBC304-18, 6.3.2.2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f_c'}}{4f_y}b_w d, \frac{1.4}{f_y}b_w d\right) \rightarrow minimum\ steel\ area, SBC304-9.6.1.2$$

$$A_{sf} = \frac{0.85f_c'(b_e - b_w)h_f}{f_y} \rightarrow Area\ of\ steel\ balancing\ compression\ force\ in\ flange$$

$$A_{sw} = A_s - A_{sf} \rightarrow Area\ of\ steel\ balancing\ compression\ force\ in\ web$$



Design the T beam for the floor system shown below when subjected to an ultimate moment of 250 kN. m Beam span is 4.8 m. b_w and d are given as 300 and 400 mm respectively (one layer expected). Use f'_c = 25 MPa, f_y = 420 MPa, d_s=10 mm, and d_b 28.

1- Calculate effective flange width b_e:

$$b_e = min\begin{cases} b_w + 16h_f & = 300 \times 16 \times 100 = 1900\ mm \\ b_w + s_w = 300 + 2700 & = 3000\ mm \\ b_w + \frac{l_n}{4} = 300 + \frac{4800}{4} & = 1500\ mm \end{cases}$$

$$b_e = 1500\ mm$$

2- Find, ρ and $A_{s\ min}$: and A_s

Assume steel is yielding and Ø = 0.9.

$$R_n = \frac{M_u}{Øb_e d^2} = \frac{250 \times 10^6}{0.9 \times 1500 \times 400^2} = 1.1574$$

$$\rho = \frac{0.85 f_c'}{f_y}\left(1 - \sqrt{1 - \frac{4R_n}{1.7 f_c'}}\right) = \frac{0.85 \times 25}{420}\left(1 - \sqrt{1 - \frac{4 \times 1.1574}{1.7 \times 25}}\right) = 0.0028350$$

$$A_s = \rho b_e d = 0.0028350 \times 1500 \times 400 = 1701\ mm^2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f_c'}}{4f_y} b_w d, \frac{1.4}{f_y} b_w d\right) = Max\left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 400, \frac{1.4}{420} \times 300 \times 400\right)$$

$$A_{s,min} = 400\ mm^2$$

Use 3Ø28 $A_{s\ provided}$ = 3 × π 28^2 /4 = 1847 mm^2

$A_s \geq A_{s\ min}$ ➔ ✓

3- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a \leq h_f$:

$$a = \frac{A_s f_y}{0.85 f_c' b_e} = \frac{1847 \times 420}{0.85 \times 25 \times 1500} = 24.33\ mm$$

24.33 < 100 ➔ assumption satisfied. Design as rectangular.

f'_c = 25 MPa < 28 ➔ β_1 = 0.85

$$c = \frac{a}{\beta_1} = \frac{24.33}{0.85} = 28.63\ mm$$

4- Check assumption (steel is yielding) at most top steel layer, d_{min}

$$one\ layer\ \rightarrow d = d_t = d_{min} = 400\ mm$$

$$\varepsilon_{min} = \left(\frac{d_{min} - c}{c}\right)\varepsilon_{cu} = \left(\frac{400 - 28.63}{28.63}\right) \times 0.003 = 0.0.0389 \geq \varepsilon_y$$

0.0389 ≥ 0.0021 ➔ steel is yielding

5- Find Ø:

Check strain at bottom layer

$$\varepsilon_t = \left(\frac{d_t - c}{c}\right)\varepsilon_{cu} = \left(\frac{400 - 28.63}{28.63}\right) \times 0.003 = 0.0.0389$$

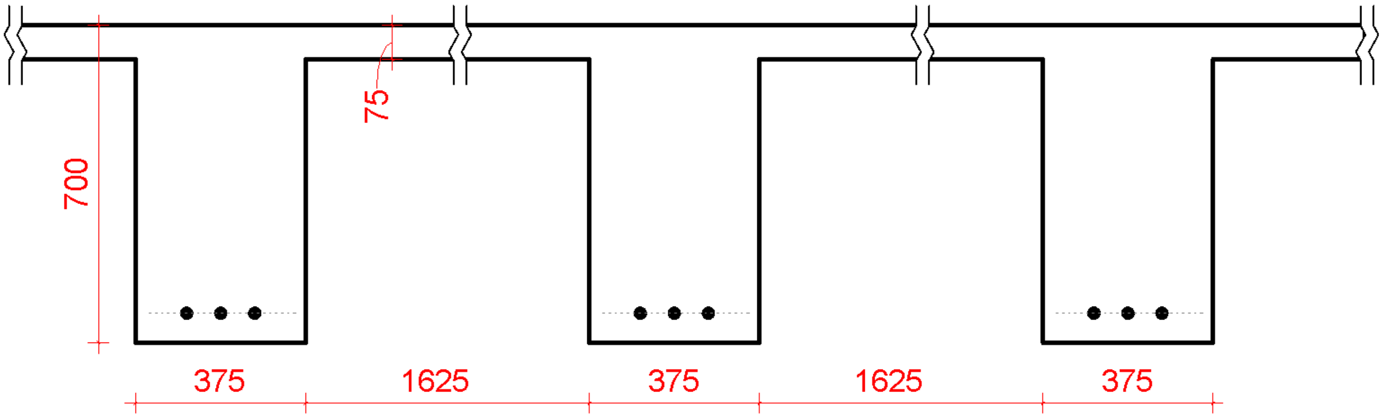
0.0389 ≥ 0.005 ➔ tension control ➔ Ø = 0.9

6- Check $ØM_n \geq M_u$:

$$\emptyset M_n = \emptyset A_s f_y \left(d - \frac{a}{2}\right) = 0.9 \times 1847 \times 420 \left(400 - \frac{24.33}{2}\right) = 300.8 \times 10^6 N.mm$$

$$\emptyset M_n = 300.8\ kN.m\ \geq M_u = 250\ kN.m$$

■■■■



Design the T beam for the floor system shown below when subjected to an ultimate moment of 1400 kN. m Beam span is 4.5 m. b_w and h are given as 375 and 700 mm respectively. Use f'_c = 25 MPa, f_y = 420 MPa, d_s=10 mm, d_b=36. S_b and S_l = 30 mm.

1- Calculate effective flange width b_e:

$$b_e = min\begin{cases} b_w + 16h_f \quad = 375 \times 16 \times 75 & = 1575\ mm \\ b_w + s_w = 375 + 1625 & = 2000\ mm \\ b_w + \dfrac{l_n}{4} = 375 + \dfrac{4500}{4} & = 1500\ mm \end{cases}$$

$$b_e = 1500\ mm$$

2- Find, ρ and $A_{s\ min}$: and A_s

Assume steel is yielding, Ø = 0.9, and d= 700 – 90 = 610 mm

$$R_n = \frac{M_u}{\emptyset b_e d^2} = \frac{1400 \times 10^6}{0.9 \times 1500 \times 610^2} = 2.787$$

$$\rho = \frac{0.85 f'_c}{f_y}\left(1 - \sqrt{1 - \frac{4R_n}{1.7 f'_c}}\right) = \frac{0.85 \times 25}{420}\left(1 - \sqrt{1 - \frac{4 \times 2.787}{1.7 \times 25}}\right) = 0.00714$$

$$A_s = \rho b_e d = 0.00714 \times 1500 \times 610 = 6532.5\ mm^2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f'_c}}{4f_y} b_w d, \frac{1.4}{f_y} b_w d\right) = Max\left(\frac{\sqrt{25}}{4 \times 420} \times 375 \times 610, \frac{1.4}{420} \times 375 \times 610\right)$$

$$A_{s,min} = 762.5\ mm^2$$

Use 7Ø36 $A_{s\ provided} = 7 \times \pi\ 36^2/4 = 7125\ mm^2$

$A_s \geq A_{s\ min}$ ➔ ✓

3- Check number of layers:

$$n_{max} = \frac{b + S_b - 6d_s + d_b - 2cover}{d_b + S_b} = \frac{375 + 30 - 6 \times 10 + 36 - 2 \times 40}{36 + 30} = 4.56 \approx 4$$

Seven rebars need two layers. Four rebars are in bottom and three are in top.

4- Find effective depth, *d*:

$$d_t = h - cover - d_s - \frac{d_b}{2} = 700 - 40 - 10 - 18 = 632\, mm$$

$$d_{min} = d_t - S - d_b = 632 - 30 - 36 = 566\, mm$$

$A_{s\,1} = 4 \times \pi\, 36^2/4 = 4071.5\ mm^2$ $y_1 = 68$ mm.

$A_{s\,2} = 3 \times \pi\, 36^2/4 = 3053.5\ mm^2$ $y_2 = 134$ mm.

$$g = \frac{\sum A_{si} y_i}{A_{si}} = \frac{[4071.5 \times 68] + [3053.5 \times 134]}{(7125)} = 96.3\, mm$$

$$d = h - g = 700 - 96.3 = 603.7\, mm$$

Actual d = 603.7 mm is less than assumed d= 610 mm. $ØM_n$ must be checked.

5- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a \leq h_f$:

$$a = \frac{A_s f_y}{0.85 f_c' b_e} = \frac{7125 \times 420}{0.85 \times 25 \times 1500} = 93.88\, mm$$

93.88 > 75 ➔ assumption not satisfied. Use decomposition method.

6- Find A_{sf} and A_{sw}

$$A_{sf} = \frac{0.85 f_c' (b_e - b_w) h_f}{f_y} = \frac{0.85 \times 25 \times (1500 - 375) \times 75}{420} = 4269\, mm^2$$

$$A_s = A_{sf} + A_{sw} \rightarrow A_{sw} = A_s - A_{sf} = 7125 - 4269 = 2856\, mm^2$$

7- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a > h_f$:

$$a = \frac{A_{sw} f_y}{0.85 f_c' b_w} = \frac{2856 \times 420}{0.85 \times 25 \times 375} = 150.53\, mm$$

f'_c = 25 MPa < 28 ➔ $\beta_1 = 0.85$

$$c = \frac{a}{\beta_1} = \frac{150.53}{0.85} = 177.1\, mm$$

8- Check assumption (steel is yielding) at most top steel layer, d_{min}

$$\varepsilon_{min} = \left(\frac{d_{min} - c}{c}\right) \varepsilon_{cu} = \left(\frac{566 - 177.1}{177.1}\right) \times 0.003 = 0.00659 \geq \varepsilon_y$$

$0.00659 \geq 0.0021$ ➔ steel is yielding

9- Find Ø:

Check strain at bottom layer, d_t

$$\varepsilon_t = \left(\frac{d_t - c}{c}\right)\varepsilon_{cu} = \left(\frac{632 - 177.1}{177.1}\right) \times 0.003 = 0.0077$$

0.0077 ≥ 0.005 ➔ tension control ➔ Ø = 0.9

10- Find design moment capacity $ØM_n$

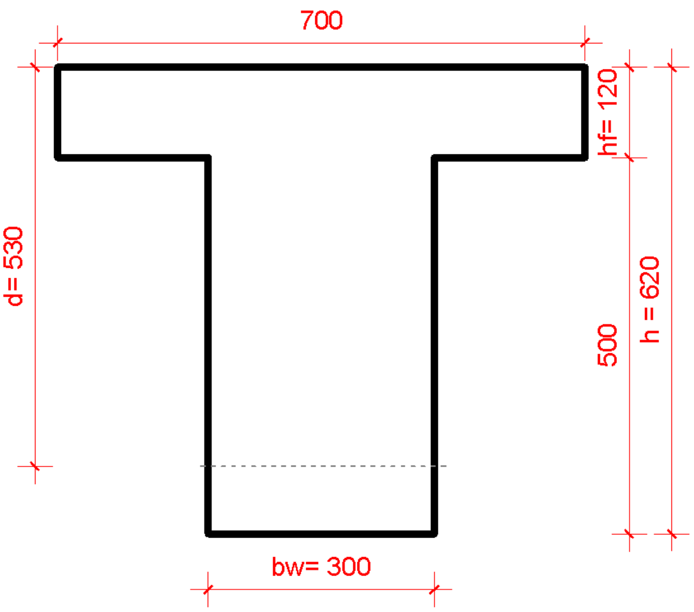
$$M_n = A_{sf} f_y \left(d - \frac{h_f}{2}\right) + A_{sw} f_y \left(d - \frac{a}{2}\right)$$

$$M_n = 4269 \times 420\left(603.7 - \frac{75}{2}\right) + 2856 \times 420\left(603.7 - \frac{155.53}{2}\right) = 1646.05 \times 10^6 N.mm$$

$$\emptyset M_n = 0.9 \times 1646.05 = 1481.5\ kN.m$$

$ØM_n \geq M_u$ ➔ ✓

■■■■



Assuming tension control condition satisfied, design the T beam shown below when subjected to an ultimate moment of 800 kN. m. Use f'_c = 25 MPa, f_y = 420 MPa, d_s=10 mm, d_b=36. S_b and S_l = 30 mm.

Assume d = 530

1- Find, ρ and $A_{s\,min}$: and A_s

Assume steel is yielding and Ø = 0.9,

$$R_n = \frac{M_u}{\emptyset b_e d^2} = \frac{800 \times 10^6}{0.9 \times 700 \times 530^2} = 4.521$$

$$\rho = \frac{0.85 f_c'}{f_y}\left(1 - \sqrt{1 - \frac{4R_n}{1.7 f_c'}}\right) = \frac{0.85 \times 25}{420}\left(1 - \sqrt{1 - \frac{4 \times 4.521}{1.7 \times 25}}\right) = 0.0122$$

$$A_s = \rho b_e d = 0.0122 \times 700 \times 530 = 4543\ mm^2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f_c'}}{4 f_y} b_w d, \frac{1.4}{f_y} b_w d\right) = Max\left(\frac{\sqrt{25}}{4 \times 420} \times 375 \times 610, \frac{1.4}{420} \times 375 \times 610\right)$$

$$A_{s,min} = 530\ mm^2$$

Use 5Ø36 $A_{s\,provided}$ = 5 × π 36^2 /4 = 5090 mm^2

$A_s \geq A_{s\,min}$ ➔ ✓

2- Check number of layers:

$$n_{max} = \frac{b + S_b - 6d_s + d_b - 2cover}{d_b + S_b} = \frac{300 + 30 - 6 \times 10 + 36 - 2 \times 40}{36 + 30} = 3.42 \approx 3$$

Five rebars need two layers. Three rebars are in bottom and two are in top.

3- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a \le h_f$:

$$a = \frac{A_s f_y}{0.85 f_c' b_e} = \frac{5090 \times 420}{0.85 \times 25 \times 700} = 143.72\, mm$$

143.71 > 120 ➔ assumption not satisfied. Use decomposition method.

4- Find A_{sf} and A_{sw}

$$A_{sf} = \frac{0.85 f_c'(b_e - b_w) h_f}{f_y} = \frac{0.85 \times 25 \times (700 - 300) \times 120}{420} = 2428.5\, mm^2$$

$$A_s = A_{sf} + A_{sw} \rightarrow A_{sw} = A_s - A_{sf} = 5090 - 2428.5 = 2661.5\, mm^2$$

5- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a > h_f$:

$$a = \frac{A_{sw} f_y}{0.85 f_c' b_w} = \frac{2661.5 \times 420}{0.85 \times 25 \times 300} = 175.35\, mm$$

f'_c = 25 MPa < 28 ➔ $\beta_1 = 0.85$

$$c = \frac{a}{\beta_1} = \frac{175.35}{0.85} = 206.3\, mm$$

6- Find effective depth: d, d_{min} and d_t:

$$d_t = h - cover - d_s - \frac{d_b}{2} = 620 - 40 - 10 - 18 = 552\, mm$$

$$d_{min} = d_t - S - d_b = 552 - 30 - 36 = 486\, mm$$

$A_{s\,1} = 3 \times \pi\, 36^2/4 = 3054\ mm^2$ $y_1 = 66$ mm.

$A_{s\,2} = 2 \times \pi\, 36^2/4 = 2036\ mm^2$ $y_2 = 132$ mm.

$$g = \frac{\sum A_{si} y_i}{A_{si}} = \frac{[3054 \times 66] + [2036 \times 132]}{(5090)} = 92.4\, mm$$

$$d = h - g = 620 - 92.4 = 527.6\, mm$$

Actual d = 527.6 mm is less than assumed d= 530 mm. $ØM_n$ must be checked.

7- Check assumption (steel is yielding) at most top steel layer, d_{min}

$$\varepsilon_{min} = \left(\frac{d_{min} - c}{c}\right)\varepsilon_{cu} = \left(\frac{486 - 206.3}{206.3}\right) \times 0.003 = 0.0041 \ge \varepsilon_y$$

0.0041 ≥ 0.0021 ➔ steel is yielding

9- Find Ø: Check strain at bottom layer, d_t

$$\varepsilon_t = \left(\frac{d_t - c}{c}\right)\varepsilon_{cu} = \left(\frac{552 - 206.3}{206.3}\right) \times 0.003 = 0.00503$$

0.00503 ≥ 0.005 ➔ tension control ➔ Ø = 0.9

10- Find design moment capacity $ØM_n$

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

$$M_n = 2428.5 \times 420 \left(527.6 - \frac{120}{2}\right) + 2661.5 \times 420 \left(527.6 - \frac{175.35}{2}\right) = 968.7 \times 10^6 N.mm$$

$$\emptyset M_n = 0.9 \times 968.7 = 871.83\ kN.m$$

$ØM_n \geq M_u$ ➔ ✓

■■■■