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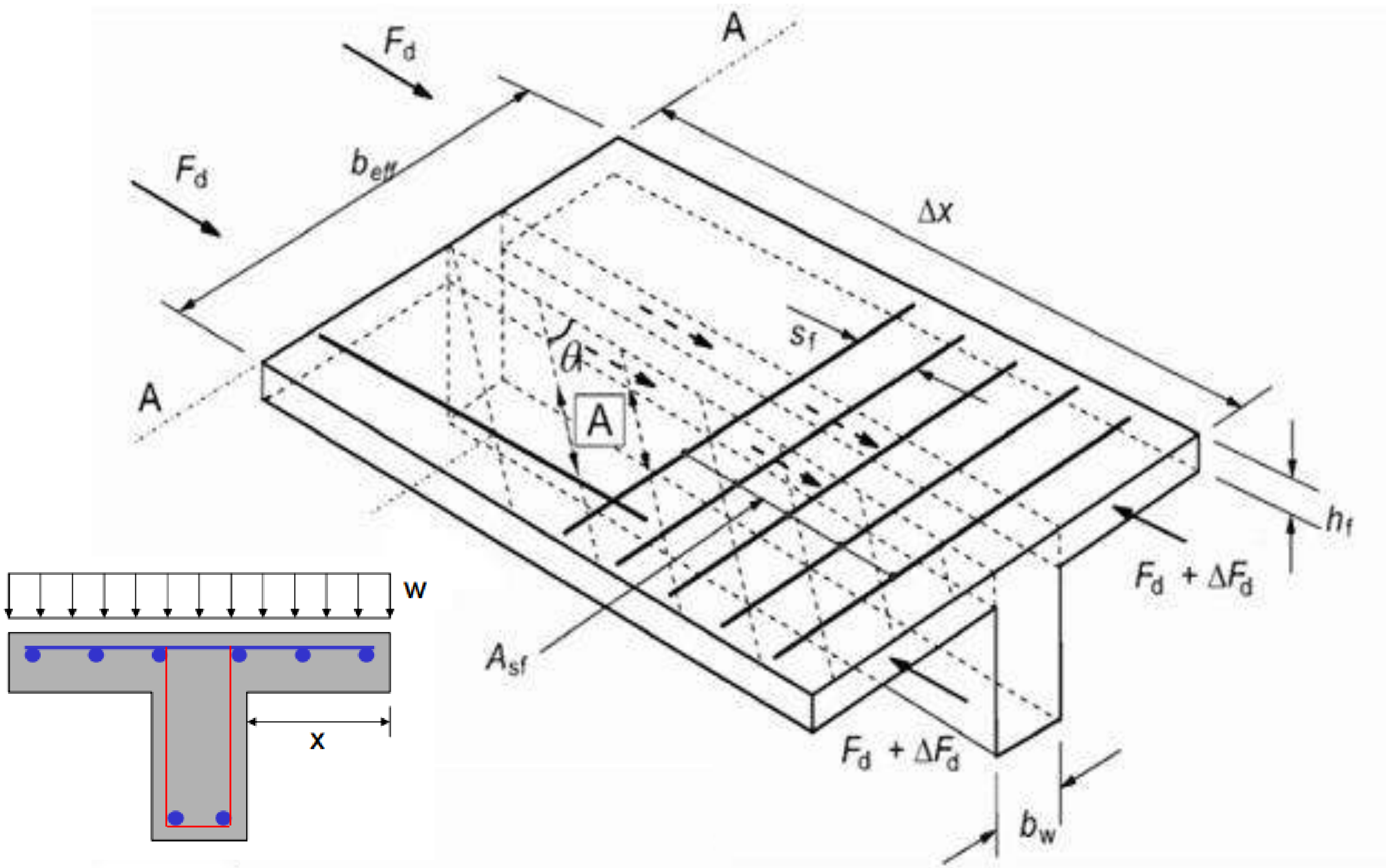
Flange Beam Design

Department of Structures and Material Engineering
Faculty of Civil and Environmental Engineering
University Tun Hussein Onn Malaysia

With Wisdom We Explore

Introduction



- Main reinforcement
- Shear reinforcement
- Traverse reinforcement

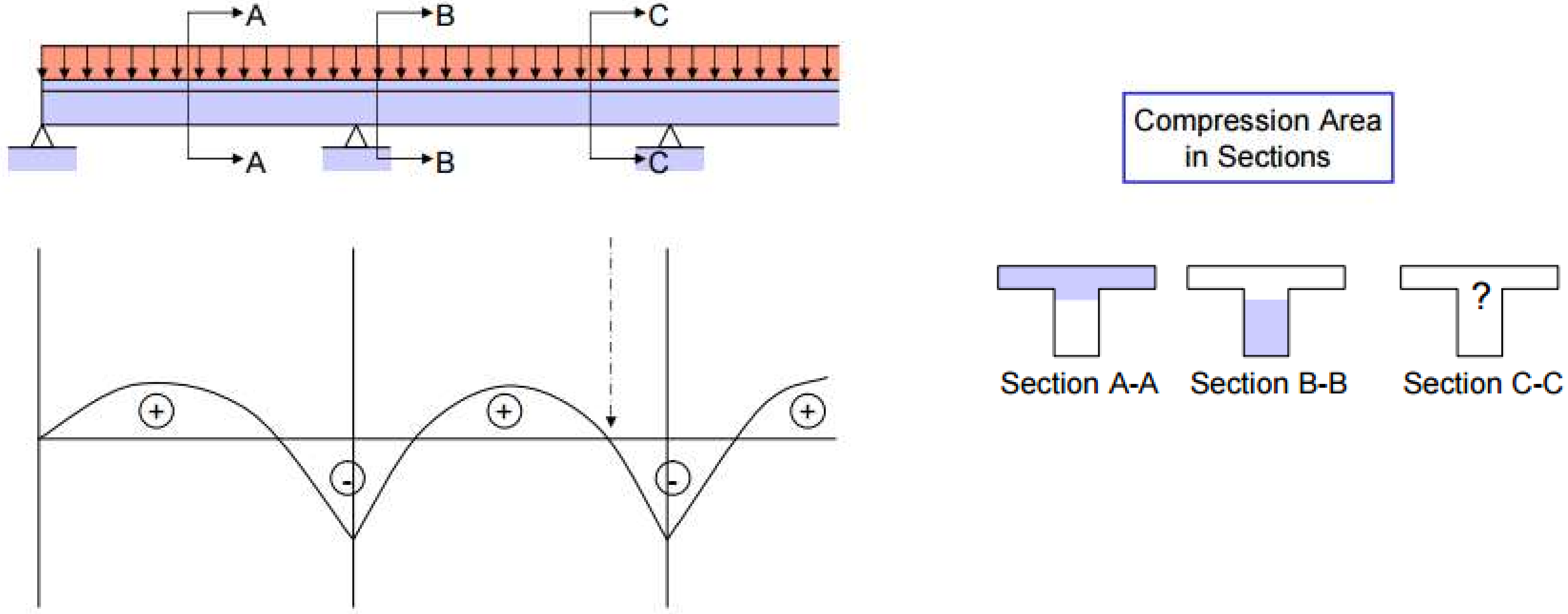
Key Different

Design Procedures

Step	Task	Standard
1	Determine design life	EN 1990:2002 Table 2.1
2	Determine beam size	EN 1992-1-1: Table 7.4N EN 1992-1-2: Table 5.5 & 5.6
3	Determine the effective width	EN 1992-1-1: Sec.5.3.2.1
4	Determine design actions on beam	EN 1991-1-1
5	Durability and characteristic strengths	EN 1992-1-1: Sec. 3 & 4
6	Determine nominal cover	EN 1991-1-1: Sec.4.4.1
7	Calculate moment and shear force	EN 1992-1-1: Sec.5
8	Design of flexural reinforcement	EN 1992-1-1: Sec.6.1, 9.2.1.1
9	Design of shear reinforcement	EN 1992-1-1: Sec.6.2
10	Design for traverse	
11	Check deflection	EN 1992-1-1: Sec.7.4
12	Check cracking	EN 1992-1-1: Sec.7.3
13	Detailing	EN 1992-1-1: Sec.8 & 9.2

Moment

- Negative moment - it should be noted that when T-beam is subjected to negative moment, the slab at top of web will be in tension while the bottom web is in compression. This usually occurs at interior support of continuous beam.



Moment

Midspan section: A-A

Case 1: Compression area in flanges and web

Behave as a composite T-section

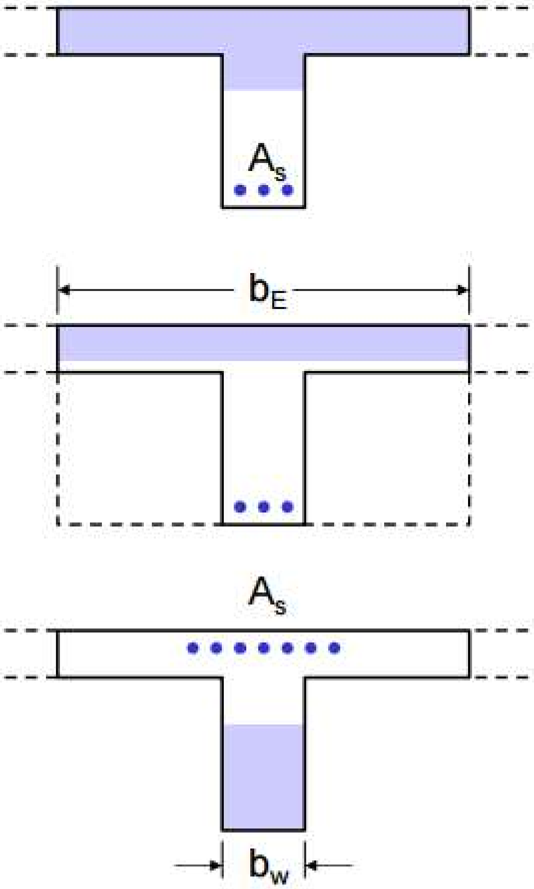
Case 2: Compression area in flanges only

Behave as a rectangular section: width = b_E

Support section: B-B

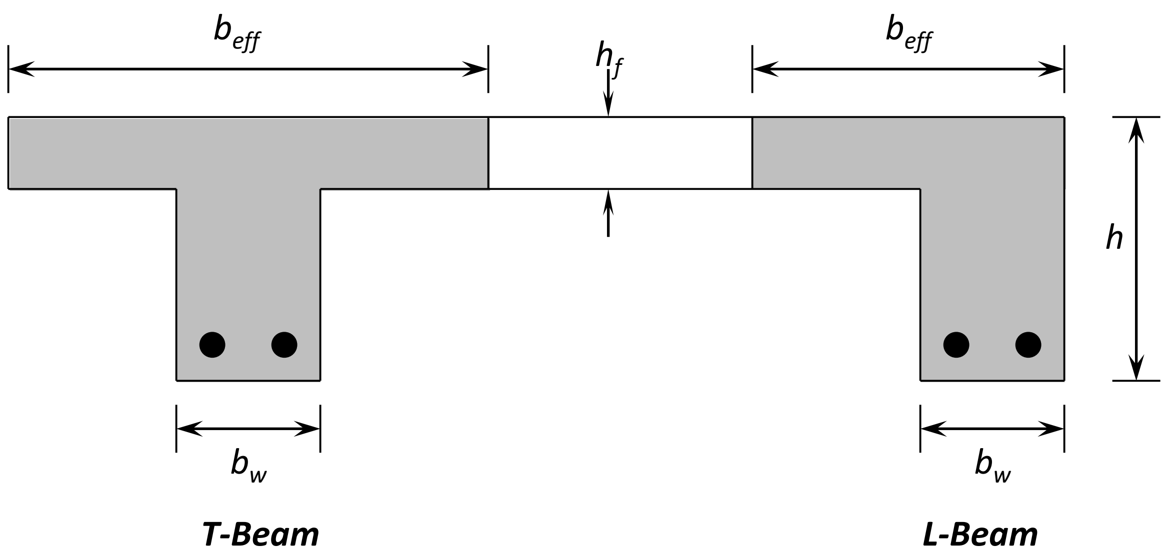
Compression area in web (flanges cracked)

Behave as a rectangular section: width = b_w



Flange Beam

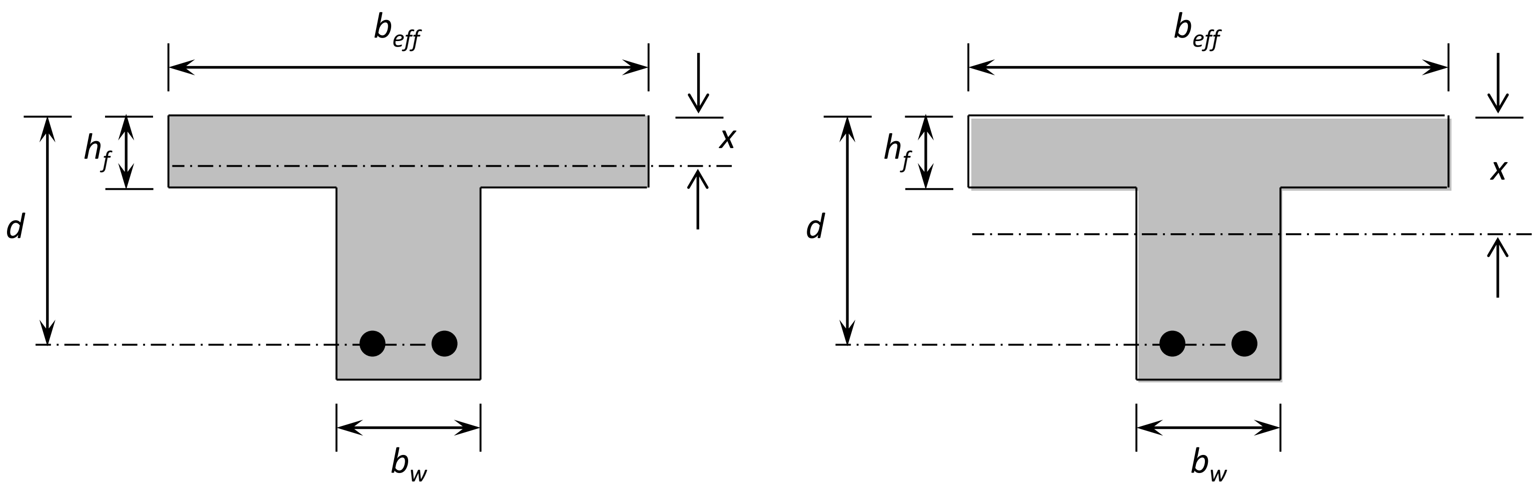
- Flanged beams occur when beams are cast integrally with and support a continuous floor slab.
- Part of the slab adjacent to the beam is counted as acting in compression to form T- and L-beam.
- The effective width of flange, b_{eff} is given in Sec. 5.3.2.1 of EC2 and should be based on the distance l_o.



where;
b_{eff} = effective flange width
b_w = breadth of the web of the beam.
h_f = thickness of the flange.

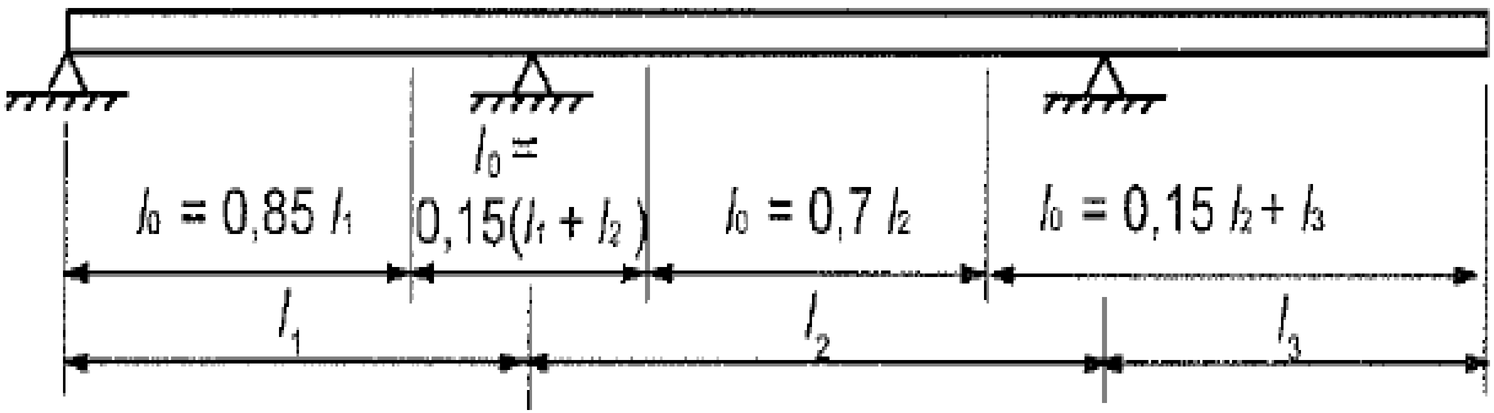
Flange Beam

- The design procedure of flange beam depends on where the neutral axis lies.
- The neutral axis may lie in the flange or in the web.
- There are three cases that should be considered:
  - Neutral axis lies in flange *($M < M_f$)*
  - Neutral axis lies in web *($M > M_f$ but $< M_{bal}$)*
  - Neutral axis lies in web *($M > M_{bal}$)*



Flange Beam

- The effective width of flange, b_{eff} is given in Sec. 5.3.2.1 of EC2.
- b_{eff} should be based on the distance l_o between points of zero moment as shown in the figure below.



Flange Beam

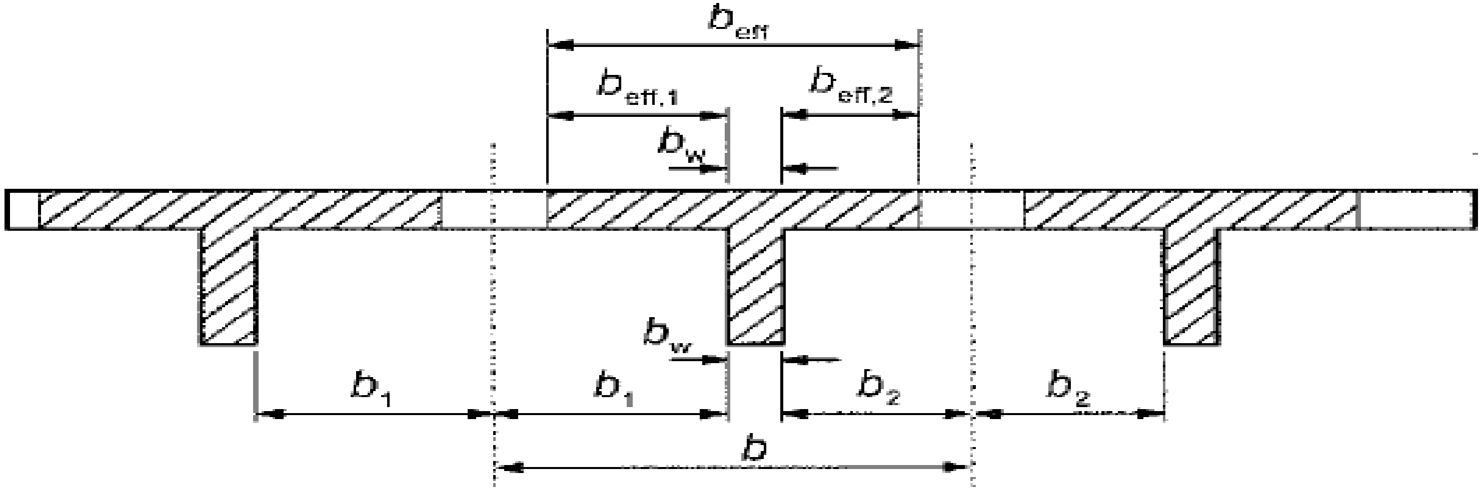
- The effective flange width, b_{eff} for T-beam or L-beam may be derived as:

$$b_{eff} = \Sigma b_{eff,i} + b_w \leq b$$

where:

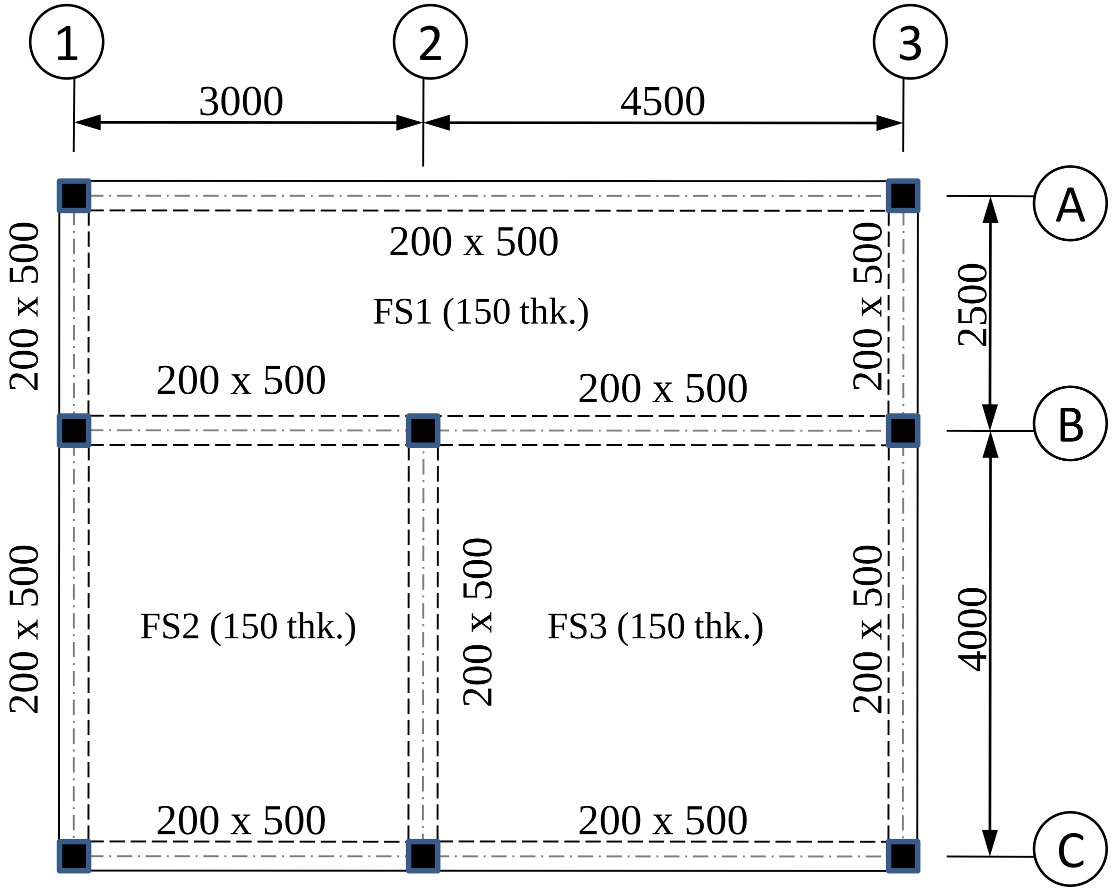
$$b_{eff,i} = 0.2b_i + 0.1l_o \leq 0.2l_o$$

$$b_{eff,i} \leq b_i$$



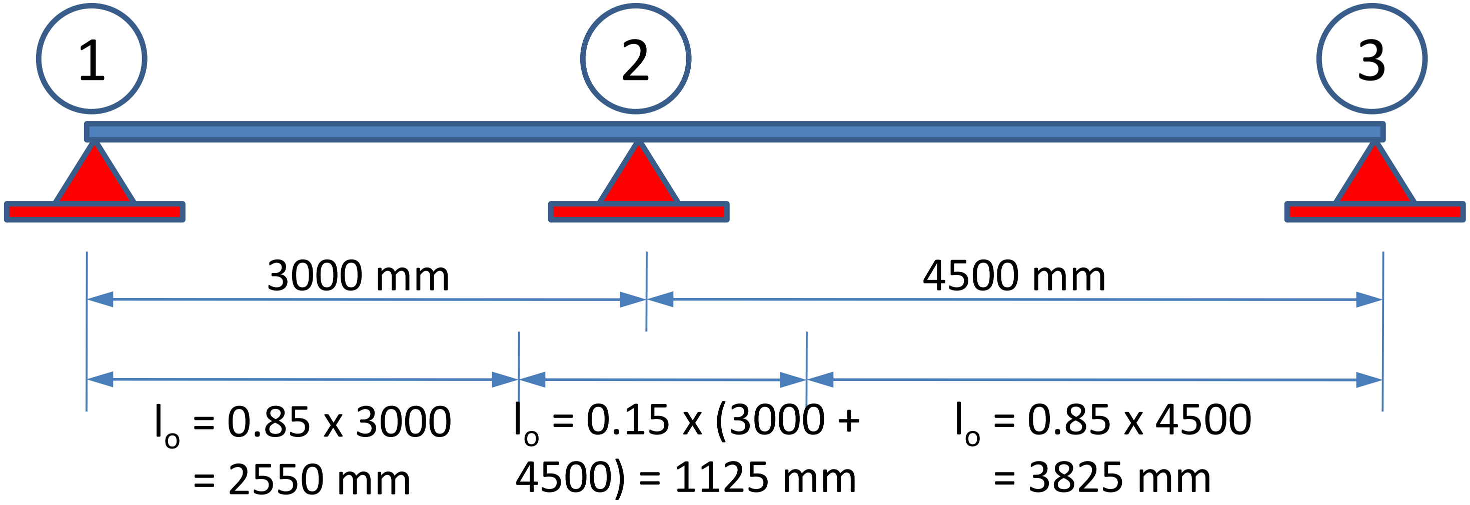
Example 1

- Based on figure below, determine the effective flange width, b_{eff} of beam B/1-3.



Example 1

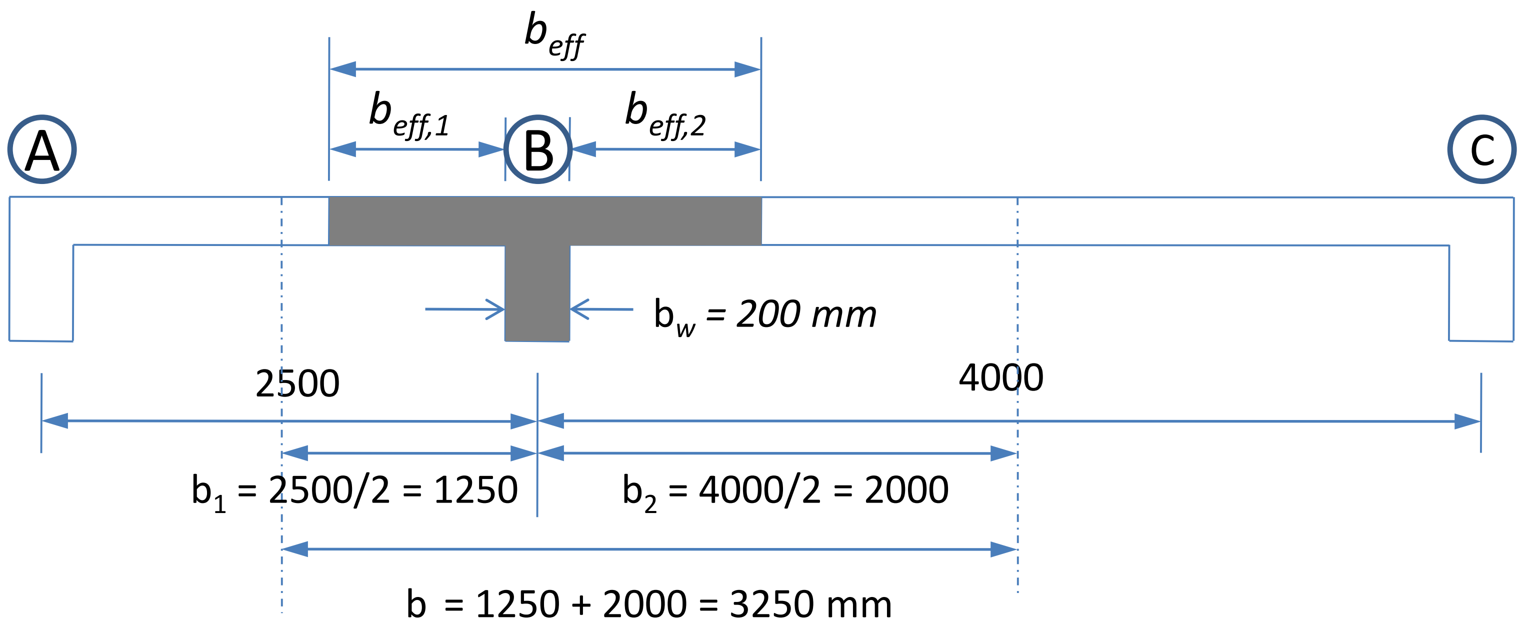
- l_o (distance between points of zero moment)



- Effective flange width, b_{eff}

$$b_{eff} = \Sigma b_{eff,i} + b_w \leq b$$

Example 1



- Span 1-2

$b_{eff1} = 0.2(1250) + 0.1(2550)$

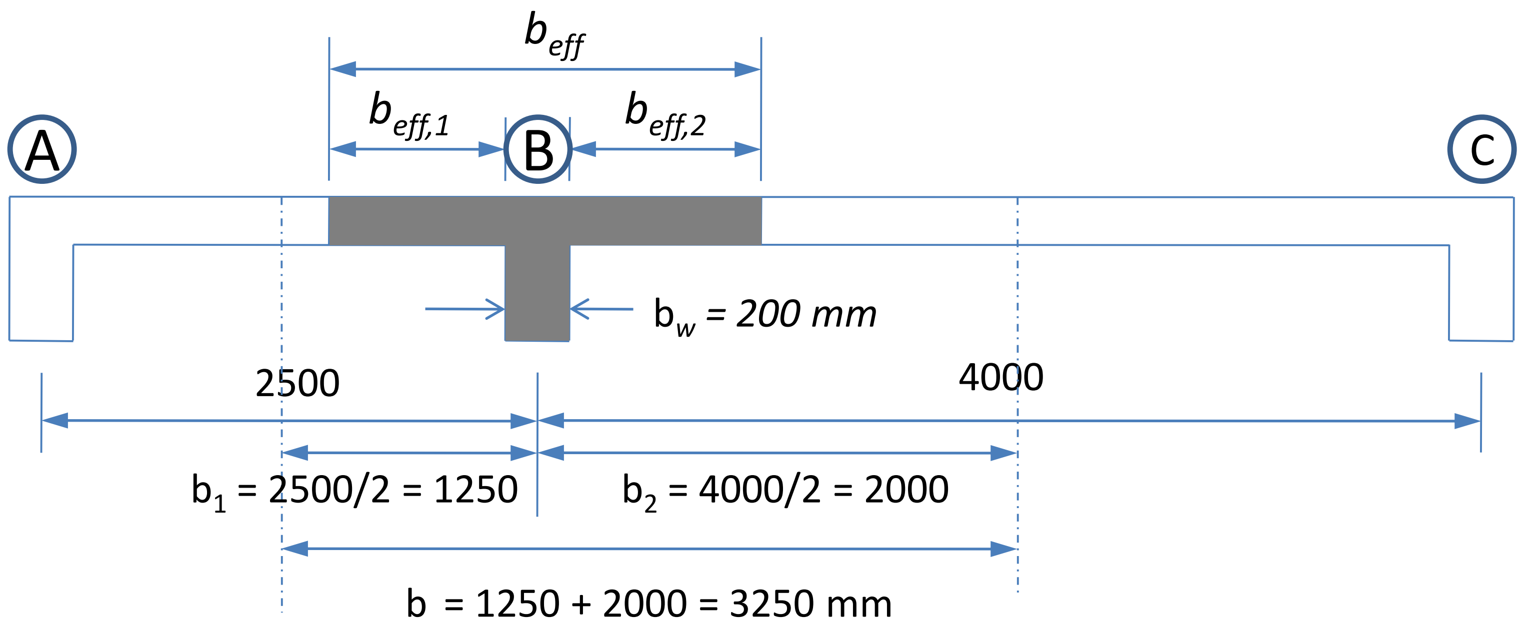
$= \mathbf{505\ mm} < 0.2l_o = 510\ mm < b_1 = 1250\ mm$

$b_{eff2} = 0.2(2000) + 0.1(2550)$

$= \mathbf{655\ mm} > 0.2l_o = 510\ mm < b_2 = 2000\ mm$

$b_{eff} = (505 + 510) + 200 = \mathbf{1215\ mm} < 3250\ mm$

Example 1



- Span 2-3:

b_{eff1} = 0.2(1250) + 0.1(3825)

= **632.5 mm** < $0.2l_o$ = 765 mm < b_1 = 1250 mm

b_{eff2} = 0.2(2000) + 0.1(3825)

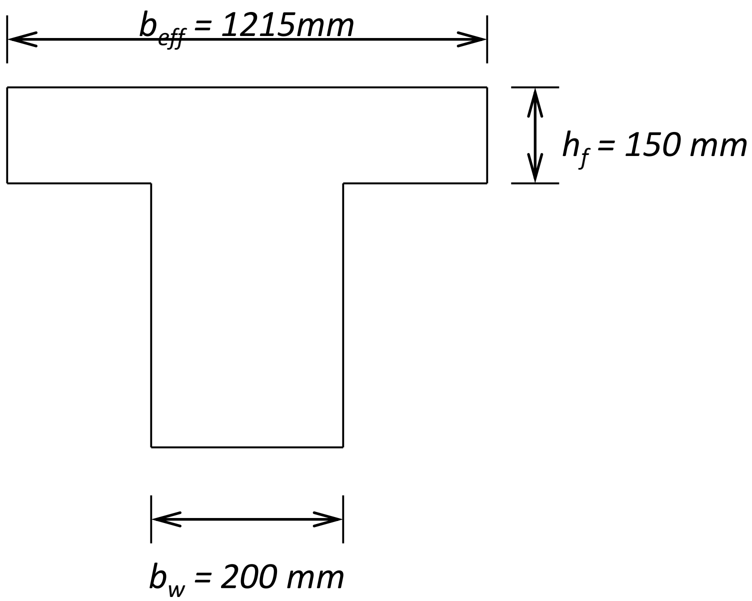
= **782.5 mm** > $0.2l_o$ = **765 mm** < b_2 = 2000 mm

b_{eff} = (632.5 + 765) + 200 = **1597.5 mm** < 3250 mm

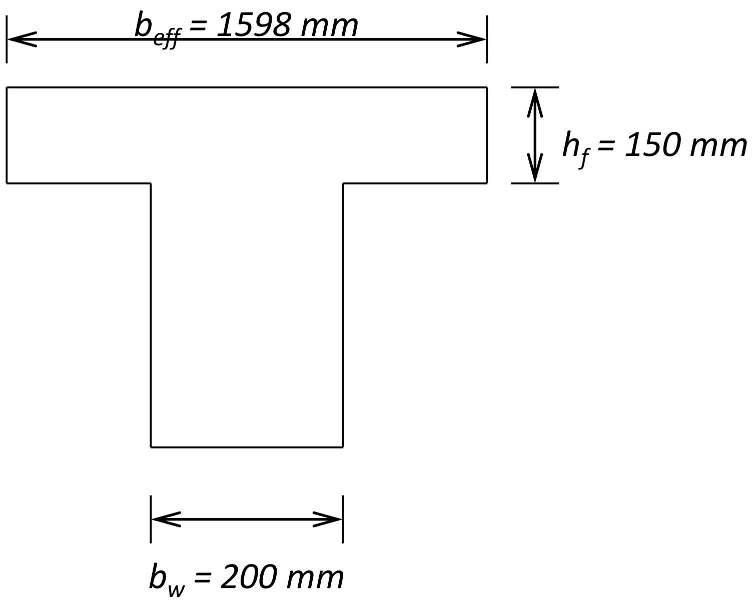
Example 1

- Dimension of flange beam:

Span 1-2



Span 2-3



Design For Flexural

- Design procedure for flange beam:

1) Calculate M_f,

$$M_f = 0.567 f_{ck} b h_f \left(d - 0.5 h_f \right)$$

2) If $M \leq M_f$, neutral axis in the flange and hence provide tensile reinforcement only

$$K = \frac{M_{Ed}}{b d^2 f_{ck}}$$

$$z = d \left[0.5 + \sqrt{0.25 - \frac{K}{1.134}} \right] \leq 0.95 d$$

$$A_{s,req} = \frac{M_{Ed}}{0.87 f_{yk} z}$$

Design For Flexural

3) If $M > M_f$, neutral axis in the web

$$\beta_f = 0.167\frac{b_w}{b} + 0.567\frac{h_f}{d}\left(1 - \frac{b_w}{b}\right)\left(1 - \frac{h_f}{2d}\right)$$

$$M_{bal} = \beta_f f_{ck} b d^2$$

$M < M_{bal}$, compression reinforcement is not required

$$A_s = \frac{M + 0.1 f_{ck} b_w d (0.36d - h_f)}{0.87 f_{yk} (d - 0.5h_f)}$$

$M > M_{bal}$, compression reinforcement is required

$$A_s' = \frac{(M - M_f)}{0.87 f_{yk} (d - d')}$$

$$A_s = \frac{0.167 f_{ck} b_w d + 0.567 f_{ck} h_f (b - b_w)}{0.87 f_{yk}} + A_s'$$

Design For Shear

- Design procedure:
  1) Determine design shear force, V_{Ed}
  2) Determine the concrete strut capacity for *cot θ =1.0* and *cot θ =2.5* (*θ = 22°* and *θ = 45°* respectively)

$$V_{Rd,\max} = \frac{0.36 b_w d f_{ck} \left(1 - f_{ck} / 250\right)}{\cot\theta + \tan\theta}$$

Cl.6.2.3 (3)

If $V_{Ed} > V_{Rd,max}$ *cot θ = 1.0 (θ = 45°)*, redesign the section

If $V_{Ed} < V_{Rd,max}$ *cot θ = 2.5*, use *cot θ = 2.5 (θ = 22°)*, and calculate the shear reinforcement as follows,

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta} \quad ; \quad \left(\cot\theta = 2.5\right)$$

Design For Shear

If $V_{Rd,max}\ cot\ \theta = 2.5 < V_{Ed} < V_{Rd,max}\ cot\ \theta = 1.0$

$$\theta = 0.5\sin^{-1}\left[\frac{V_{Ed}}{0.18 b_w d f_{ck}\,(1 - f_{ck}\ /\ 250\,)}\right]$$

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta}$$

3) Maximum spacing

$$s < 0.75d$$

Maximum spacing

4) Calculate the minimum links,

$$\frac{A_{sw}}{s} = \frac{0.08 b_w \sqrt{f_{ck}}}{f_{yk}}$$

Cl.9.2.2(5)

Design for Traverse

- Design procedure:
  1) Determine distance Δx=0.5(L/2) which is the greatest longitudinal shear stresses.
  2) Change of moment over distance Δx

$$\Delta M = \frac{3wL^2}{32}$$

  3) Change in longitudinal force

$$\Delta F_d = \left(\frac{\Delta M}{d - 0.5h_f}\right)\left(\frac{b - b_w}{2b}\right)$$

  4) Calculate longitudinal shear stress

$$v_{ed} = \frac{\Delta F_d}{h_f \Delta x} > 0.27 f_{ctk}$$

Traverse shear reinforcement is required

Design for Traverse

5) Check concrete strut capacity in flange

$$v_{ed,\max} = \frac{0.4f_{ck}\left(1 - f_{ck}\ /\ 250\right)}{\cot\theta + \tan\theta}$$

6) Traverse shear reinforcement

$$\frac{A_{sf}}{s_f} = \frac{v_{ed} h_f}{0.78 f_{yk} d \cot\theta}$$

7) Calculate minimum traverse reinforcement area

$$A_{s,\min} = 0.26\left(\frac{f_{ctm}}{f_{yk}}\right) b h_f$$

8) Check additional longitudinal reinforcement

$$A_{s,td} = \frac{0.5 V_{Ed} \cot\theta}{0.87 f_{yk}}$$

Deflection

- To control deflection to a maximum of span/250.
- Procedure:

1) Calculate $\rho_o = \sqrt{f_{ck}}\ 10^{-3}$
2) Calculate $\rho = A_{s,req} / bd$
3) Calculate $\rho' = A_{s',req} / bd$
4) Determine K and calculate l/d

Cl.9.2.2(5)

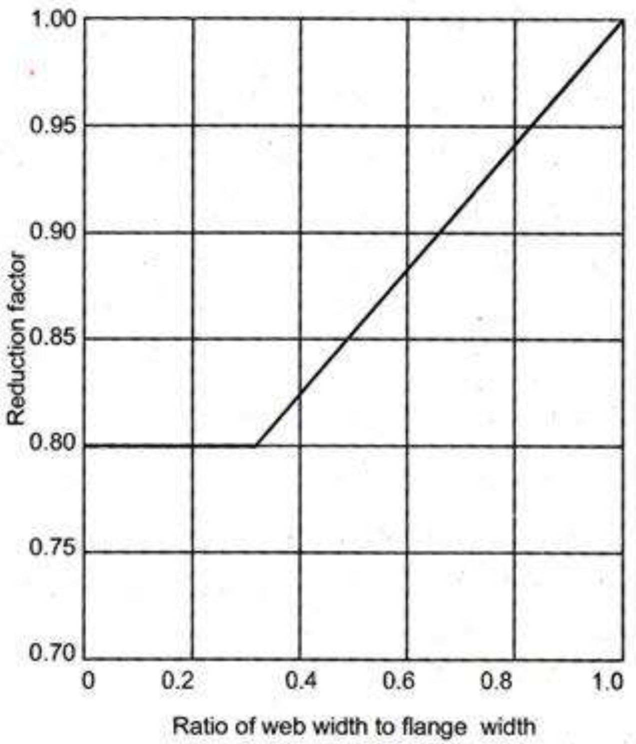
$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_o}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_o}{\rho} - 1\right)^{3/2}\right] \quad ; \quad \rho \le \rho_o$$

$$\frac{l}{d} = K\left[11 + 1.5\sqrt{f_{ck}}\frac{\rho_o}{\rho - \rho'} + \frac{1}{12}\sqrt{f_{ck}}\sqrt{\frac{\rho'}{\rho}}\right] \quad ; \quad \rho > \rho_o$$

5) Calculate modification factor MF_{flange}, MF_{span} and MF_{area}
6) For adequate deflection control, $(l/d)_{actual} < (l/d)_{allow}$

Deflection

- MF_{flange}
  - In Cl. 7.4.2(2), $b_f/b_w > 3$, $Mf_{flange} = 0.8$
  - Or $b_w/b_f \leq 0.3$, $Mf_{flange} = 0.8$, and for any, it should be determined using the following graph.



Deflection

- Factor for structural system can be determined from Table 7.4N:

Structural System		K	Basic span-effective depth ratio	
			Concrete highly stressed, ρ=1.5%	Concrete lightly stressed, ρ=0.5%
1	Simply supported beam, one/two-way simply supported slab	1.0	14	20
2	End span of continuous beam or one-way continuous slab or two-way spanning slab continuous over one long side	1.3	18	26
3	Interior span of beam or one-way or two-way spanning slab	1.5	20	26
4	Slab supported on columns without beam (flat slab) based on longer span	1.2	17	24
5	Cantilever	0.4	6	8

Cracking

- Crack control for beam design can be directly referred to Cl.7.3.
- For a convenient, crack control without direct calculation is preferable, Cl. 7.3.3, Table 7.2N and Table 7.3N.
- Procedure:
  1) Calculate steel stress for limiting crack width, $w_k = 0.3\text{mm}$

$$f_s = 435\left[\frac{G_k + 0.3Q_k}{1.35G_k + 1.5Q_k}\right]\left(\frac{A_{s,req}}{A_{s,prov}}\right)$$

Table 7.2N

  2) Determine maximum bar size or bar spacing

Table 7.3N

  3) For adequate crack control,

$$S_{prov} < S_{max}$$

Cracking

- Maximum bar spacing for crack control (Table 7.3N)

Steel Stress (N/mm2)	Maximum Bar Spacing (mm)		
	w_k = 0.4mm	w_k = 0.3mm	w_k = 0.2mm
160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
320	150	100	-
360	100	50	-