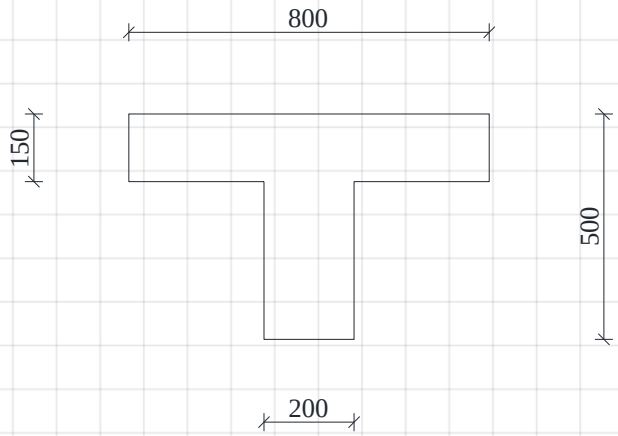
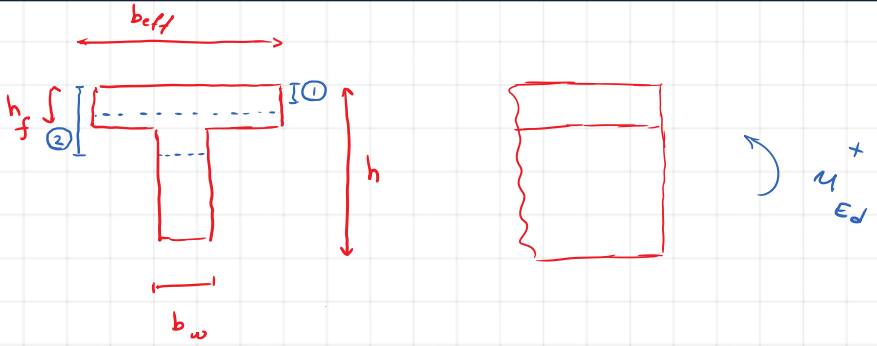
In a T-Section made of concrete, determine the procedure of how the beam can be designed for a specific design bending moment. Consider the Eurocode 1992-1-1 and Finnish National Annex.

Based on the procedure, determine the number of T20 or T25 that the given cross-section below needs to withstand the design bending moment of $M_{Ed} = 300kN.m$.

The concrete class is C30/37 reinforced by B500 steel. The nominal cover is assumed to be 35mm and the stirrup is assumed to be T10. The given dimensions are in mm.





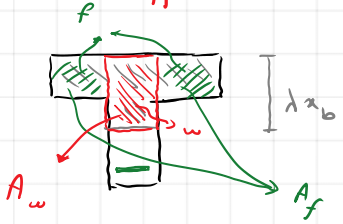
$$A_{sb} \rightarrow (\varepsilon_{cu}, \varepsilon_{yd}) \rightarrow x_b = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{yd}} \cdot d$$

① $\lambda \cdot x_b \leq h_f$ → flange partially will be in compression

② $\lambda \cdot x_b > h_f$ ⇒ flange & web (partially) will be in compression

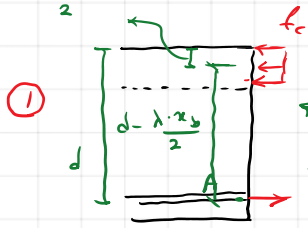
① → $A_{cb} = b_{eff} \cdot \lambda \cdot x_b$

② →



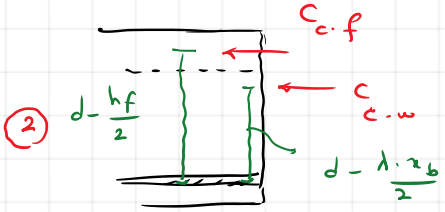
$$A_{cb} = h_f \cdot (b_{eff} - b_w) + b_w \cdot \lambda \cdot x_b$$

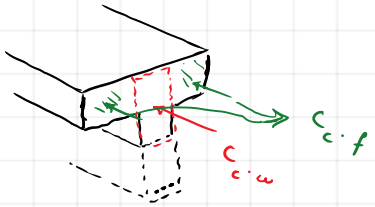
$$C = T \rightarrow \begin{cases} C_c = A_{cb} \cdot f_{cd} \\ T = A_{sb} \cdot f_{yd} \end{cases} \rightarrow A_{sb} = A_{cb} \cdot \frac{f_{cd}}{f_{yd}}$$



① $C_c = f_{cd} \cdot \lambda \cdot x_b \cdot b_{eff}$

$$M_{Rd,c} = C_c \cdot \left(d - \frac{\lambda \cdot x_b}{2}\right) = f_{cd} \cdot \lambda \cdot x_b \cdot b_{eff} \cdot \left(d - \frac{\lambda \cdot x_b}{2}\right)$$



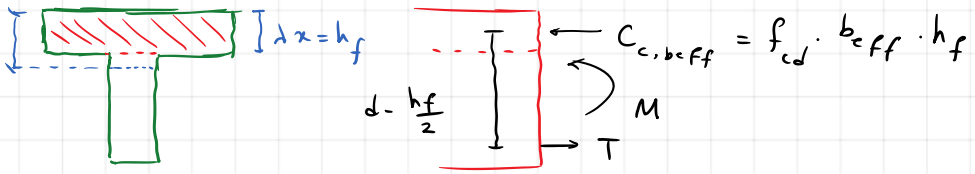
② 

$$M_{Rd,c} = C_{cf} \cdot \left(d - \frac{h_f}{2}\right) + C_{c \cdot w} \cdot \left(d - \frac{\lambda \cdot x_b}{2}\right) = f_{cd} \cdot h_f \cdot (b_{eff} - b_w)\left(d - \frac{h_f}{2}\right) + f_{cd} \cdot b_w \cdot \lambda \cdot x_b \left(d - \frac{\lambda \cdot x_b}{2}\right)$$

if $M_{Ed} \leq M_{Rd,c}$ → with neglecting the effect of compressive reinforcement we can provide sufficient tensile reinforcement.

if $M_{Ed} > M_{Rd,c}$ →
- Better concrete class
- Increasing the dimensions.
- using the capacity of compressive reinforcement.

$M_{Ed} \leq M_{Rd,c}$

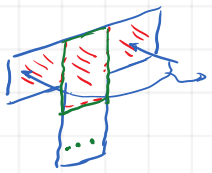


$$M_{Rd,beff} = f_{cd} \cdot b_{eff} \cdot h_f \cdot \left(d - \frac{h_f}{2}\right)$$

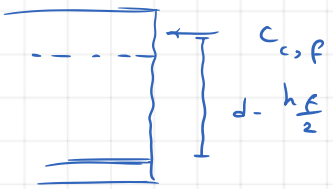
① $M_{Ed} \leq M_{Rd,beff}$ → The compressive height of the section to resist the design bending moment (M_{Ed}) is less than h_f

$$\mu = \frac{M_{Ed}}{f_{cd} \cdot b_{eff} \cdot d^2} \rightarrow \beta = 1 - \sqrt{1 - 2\mu} \rightarrow A_{s,req} = \beta \cdot \frac{f_{cd}}{f_{yd}} \cdot b_{eff} \cdot d$$

② $M_{Ed} > M_{Rd,beff}$ → The compressive height of the section is greater than h_f:



$$C_{c,f} = f_{cd} \cdot (b_{eff} - b_w) \cdot h_f$$



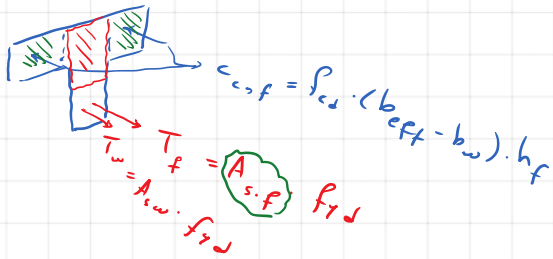
$$M_{Rd,f} = C_{c,f} \cdot \left(d - \frac{h_f}{2}\right) = f_{cd} \cdot (b_{eff} - b_w) \cdot h_f \left(d - \frac{h_f}{2}\right)$$

$$M_{Ed,w} = M_{Ed} - M_{Rd,f}$$

$\left\{ \begin{matrix} b_w \\ d \\ M_{Ed,w} \end{matrix} \right. \rightarrow \quad \mu_w = \frac{M_{Ed,w}}{f_{cd} \cdot b_w \cdot d^2}$

$\beta_w = 1 - \sqrt{1 - 2\mu_w}$

$A_{sw} = \beta_w \cdot \frac{f_{cd}}{f_{yd}} \cdot b \cdot d$



$T_f = C_{c,f} \Rightarrow$

$A_{s,f} = \frac{f_{cd} \cdot (b_{eff} - b_w) \cdot h_f}{f_{yd}}$

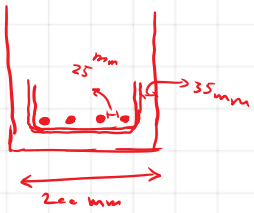
$$A_{s,rqd} = A_{sw} + A_{s,f}$$

Width of the web	$b_w := 200\ mm$
Effective Width	$b_{eff} := 800\ mm$
Height of the beam	$h := 500\ mm$
Height of the flange	$h_f := 150\ mm$
Nominal cover	$c_{nom} := 35\ mm$
Reinforcement Diameter	$\phi_s := 25\ mm$
Stirrup Diameter	$\phi_{sw} := 10\ mm$
Design Bending Moment	$M_{Ed} := 300\ kN \cdot m$
Concrete Compressive Strength	$f_{ck} := 30\ MPa$

$Status_1$ = "Compressive Reinforcement is not Required"	$A_s = 1668\ mm^2$
	$n_{s.rqd} = 3.399$
Required Reinforcement (Number)	$n := 4$

min width :

$4 \times 25\,mm \times 1.1 + 2 \times 1.1 \times 10\,mm + 3 \times 25\,mm + 2 \times 35\,mm = 277\,mm$



4T25

This does not fit