For a given rectangular concrete beam, according to Eurocode 1992-1-1:

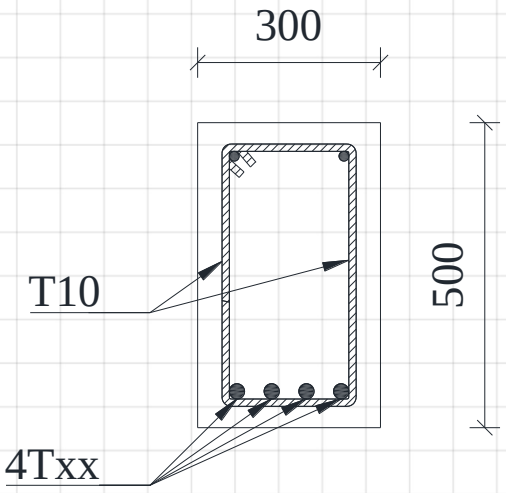
a) Determine the procedure for calculating the resistance bending moment

A concrete rectangular cross-section, 300x500, is made of C30/37 and reinforced by B500 steel. Assume the stirrup is T10 and the required nominal cover is 35mm:

b) With 4T20, determine the bending moment resistance.
c) With 4T25, determine the bending moment resistance.
d) With 4T32, determine the bending moment resistance.
e) Compare the steel percentage increase results and the corresponding bending moment increase.

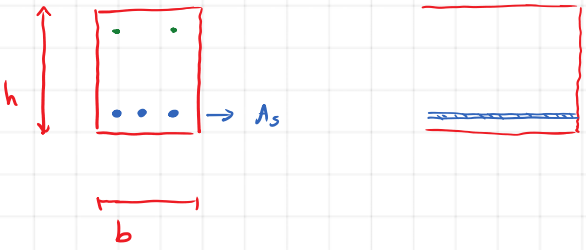
PS. Neglect the effect of compressive steel.

Dimensions are in mm. A positive bending moment is assumed to be applied.



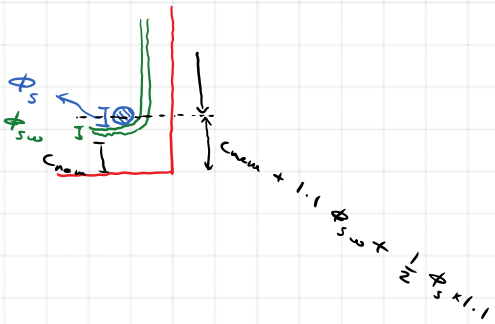
$$\omega = \frac{A_s}{b \cdot d} \cdot \frac{f_{yd}}{f_{cd}}$$

$$\beta_{bd} = \frac{A_{sb}}{b \cdot d} \cdot \frac{f_{yd}}{f_{cd}} \rightarrow f_{yk} = 500\,MPa \rightarrow \beta_{bd} = 0.493$$



$$M = \mu \cdot f_{cd} \cdot b \cdot d^2$$

$$\mu = \beta \left(1 - \frac{\beta}{2}\right)$$



① $f_{ck}, f_{yk}, f_{cd}, f_{yd}, b, h, A_s, c_{nom}$

② $d = h - c_{nom} - 1.1\,\phi_{sw} - 1.1\,\frac{\phi_s}{2}$

③ $\omega = \frac{A_s}{b \cdot d} \cdot \frac{f_{yd}}{f_{cd}}$

④ if $\omega < \beta_{bd} \rightarrow \beta = \omega$
if $\omega > \beta_{bd} \rightarrow \beta = \beta_{bd}$
$\rightarrow \beta = \min\{\omega, \beta_{bd}\}$

⑤ $\mu = \beta\left(1 - \frac{\beta}{2}\right)$

⑥ $M_{Rd} = \mu \cdot f_{cd} \cdot b \cdot d^2$

Example: C30/37 $\rightarrow f_{ck} = 30\,MPa$

$f_{yk} = 500\,MPa$

$b = 300\,mm$ $\quad c_{nom} = 35\,mm$

$h = 500\,mm$ $\quad$ stirrup: T10

longitudinal: 4T20

$\rightarrow M_{Rd} = ?$

Width of the beam		$b := 300\ mm$
Height of the beam		$h := 500\ mm$
Nominal cover		$c_{nom} := 35\ mm$
Reinforcement Diameter	4T20	$\phi_s := 20\ mm$
Stirrup Diameter		$\phi_{sw} := 10\ mm$
Number of Reinforcement		$n_s := 4$
Concrete Compressive Strength		$f_{ck} := 30\ MPa$
Bending Moment Resistance		$M_{Rd} := \mu \cdot f_{cd} \cdot b \cdot d^2 = 213\ kN \cdot m$
Tensile Reinforcement Area		$A_s = 1257\ mm^2$

Width of the beam		$b := 300\ mm$
Height of the beam		$h := 500\ mm$
Nominal cover		$c_{nom} := 35\ mm$
Reinforcement Diameter	4T25	$\phi_s := 25\ mm$
Stirrup Diameter		$\phi_{sw} := 10\ mm$
Number of Reinforcement		$n_s := 4$
Concrete Compressive Strength		$f_{ck} := 30\ MPa$
Bending Moment Resistance		$M_{Rd} := \mu \cdot f_{cd} \cdot b \cdot d^2 = 304\ kN \cdot m$
Tensile Reinforcement Area		$A_s = 1963\ mm^2$

Width of the beam		$b := 300\ mm$
Height of the beam		$h := 500\ mm$
Nominal cover		$c_{nom} := 35\ mm$
Reinforcement Diameter	4T32	$\phi_s := 32\ mm$
Stirrup Diameter		$\phi_{sw} := 10\ mm$
Number of Reinforcement		$n_s := 4$
Concrete Compressive Strength		$f_{ck} := 30\ MPa$
Bending Moment Resistance		$M_{Rd} := \mu \cdot f_{cd} \cdot b \cdot d^2 = 361\ kN \cdot m$
Tensile Reinforcement Area		$A_s = 3217\ mm^2$

$\frac{A_{s1}}{A_{s1}} = 1.56$

$\frac{M_{Rd2}}{M_{Rd1}} = 1.43$

$\frac{A_{s3}}{A_{s2}} = \frac{3217}{1963} = 1.64$

$\frac{M_{Rd3}}{M_{Rd2}} = \frac{361}{304} = 1.19$