RC Beam Design to Eurocode 2

Input data

Beam and cross section dimensions

Beam length - $L = 10\ \mathrm{m}$

Cross section dimensions: height - $h = 700\ \mathrm{mm}$, width - $b = 250\ \mathrm{mm}$

Loads

Uniformly distributed load - $q = 12\ \mathrm{kN/m}$ (total, factored)

Materials

Concrete

Characteristic compressive cylinder strength - $f_{ck} = 20\ \mathrm{MPa}$

Partial safety factor fWor concrete - $\gamma_c = 1.5$, $\alpha_{cc} = 0.85$

Design compressive cylinder strength - $f_{cd} = \dfrac{\alpha_{cc} \cdot f_{ck}}{\gamma_c} = 11.33\ \mathrm{MPa}$

Factor for effective compression zone depth - $\lambda = 0.8$

Effective compressive strength factor - $\eta = 1$

Ultimate compressive strain - $\varepsilon_{cu3} = 0.0035$

Mean value of axial tensile strength - $f_{ctm} = 0.3 \cdot \left(\dfrac{f_{ck}}{\mathrm{MPa}} \right)^{\frac{2}{3}} \cdot \mathrm{MPa} = 2.21\ \mathrm{MPa}$

Steel

<u>Longitudinal reinforcement</u>

Characteristic yield strength - $f_{yk} = 500\ \mathrm{MPa}$

Partial safety factor for steel - $\gamma_s = 1.15$

Design yield strength - $f_{yd} = \dfrac{f_{yk}}{\gamma_s} = 434.78\ \mathrm{MPa}$

Modulus of elasticity - $E_s = 200000\ \mathrm{MPa}$

<u>Shear reinforcement</u>

Characteristic yield strength - $f_{ywk} = 500\ \mathrm{MPa}$

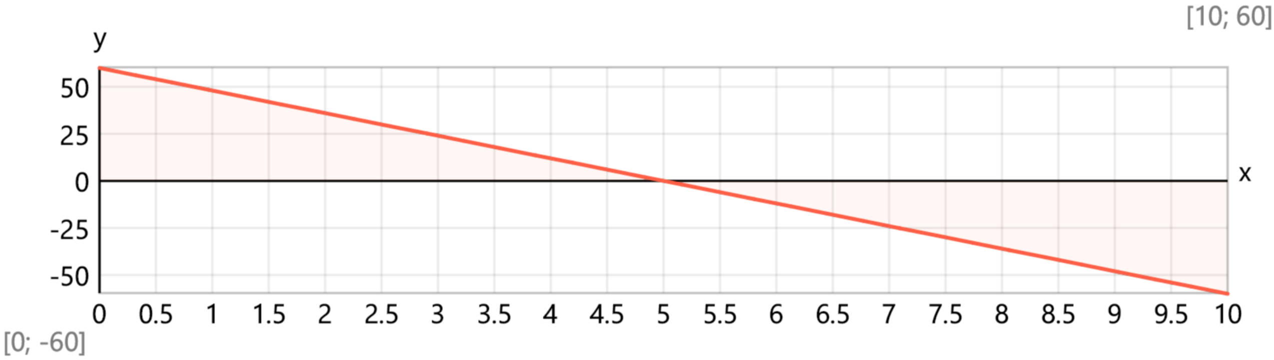
Design yield strength - $f_{ywd} = \dfrac{f_{yk}}{\gamma_s} = 434.78\ \mathrm{MPa}$

Results

Internal forces

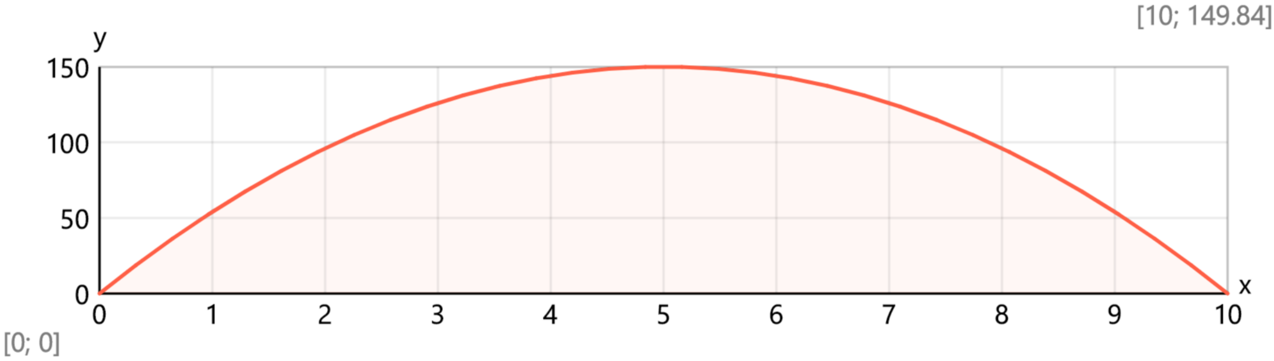
Support reaction - $A = \dfrac{q \cdot L}{2} = 60\ \mathrm{kN}$

Shear force diagram - $V(x) = A - q \cdot x$



Design shear force - $V_{Ed} = A = 60\ \mathrm{kN}$

Bending moment diagram - $M(x) = A \cdot x - \dfrac{q \cdot x^2}{2}$



Design bending moment - $M_{Ed} = \dfrac{q \cdot L^2}{8} = 150\ \mathrm{kNm}$

Bending design

Concrete cover to the center of reinforcement - $d_1 = 50\ \mathrm{mm}$

Effective cross section depth - $d = h - d_1 = 650\ \mathrm{mm}$ cm

Relative design bending moment - $m_{Ed} = \dfrac{M_{Ed}}{b \cdot d^2 \cdot \eta \cdot f_{cd}} = 0.125$

Compressive zone depth - $x = \dfrac{d}{\lambda} \cdot \left(1 - \sqrt{1 - 2 \cdot m_{Ed}}\right) = 109.14\ \mathrm{mm}$

Relative compression zone depth - $\xi = \dfrac{x}{d} = 0.168$

Design reinforcement yield strain - $\varepsilon_{yd} = \dfrac{f_{yd}}{E_s} = 0.00217$

Relative depth of compression zone at yielding of bottom reinforcement

$$\xi_{yd} = \frac{\varepsilon_{cu3}}{\varepsilon_{cu3} + \varepsilon_{yd}} = 0.617$$

Limit compression zone depth - $\xi_{lim} = \xi_{yd} = 0.617$

($\xi_{lim} = \xi_{yd}$ for elastic and $\xi_{lim} = 0.45$ for plastic analysis)

$\xi = 0.168 \le \xi_{lim} = 0.617$ - Compressive reinforcement is **NOT** required.

Lever arm of internal forces - $z = d - 0.5 \cdot \lambda \cdot x = 606.34\ \mathrm{mm}$

Required main reinforcement - $A_{sL,rq} = \dfrac{M_{Ed}}{z \cdot f_{yd}} = 568.98\ \mathrm{mm}^2$

Selected $n_b = 3$ bars with size $\varnothing_L = 20\ \mathrm{mm}$

Provided main reinforcement $A_{sL} = \dfrac{n_b \cdot \pi \cdot \varnothing_L^{\ 2}}{4} = 942.48\ \mathrm{mm}^2$

Reinforcement ratio - $\rho_L = \dfrac{A_{sL}}{b \cdot d} = 0.0058$

Minimum reinforcement ratio

$$\rho_{min} = \mathbf{max}\left(\frac{0.26 \cdot f_{ctm}}{f_{yk}}; 0.0013\right) = 0.0013 < \rho_L = 0.0058$$

Maximum reinforcement ratio - $\rho_{max} = 0.04 > \rho_L = 0.0058$

Shear design

Shear capacity without reinforcement

$k = \min\left(1 + \sqrt{\frac{200\ \mathrm{mm}}{d}}; 2\right) = 1.55$, $C_{Rd\_c} = \frac{0.18}{\gamma_c} = 0.12$, $k_1 = 0.15$, $\sigma_{cp} = 0\ \mathrm{MPa}$

$v_{min} = 0.035 \cdot k^{\frac{3}{2}} \cdot \sqrt{\frac{f_{ck}}{\mathrm{MPa}}} \cdot \mathrm{MPa} = 0.303\ \mathrm{MPa}$

$V_{Rd\_c\_} = \left(C_{Rd\_c} \cdot k \cdot \left(\frac{100 \cdot \rho_L \cdot f_{ck}}{\mathrm{MPa}}\right)^{\frac{1}{3}} \cdot \mathrm{MPa} + k_1 \cdot \sigma_{cp}\right) \cdot b \cdot d = 68.63\ \mathrm{kN}$

Minimum shear resistance

$V_{Rd\_c\_min} = (v_{min} + k_1 \cdot \sigma_{cp}) \cdot b \cdot d = 49.31\ \mathrm{kN}$

$V_{Rd\_c} = \max(V_{Rd\_c\_min}; V_{Rd\_c\_}) = 68.63\ \mathrm{kN}$

Design check:

$V_{Ed} = 60\ \mathrm{kN} \le V_{Rd\_c} = 68.63\ \mathrm{kN}$. Shear reinforcement is **NOT** required by calculations!

Nominal reinforcement will be provided as follows:

Shear links with $n_w = 2$ legs and diameter - $d_w = 6\ \mathrm{mm}$

Area of one leg - $A_{sw1} = \pi \cdot \left(\frac{d_w}{2}\right)^2 = 28.27\ \mathrm{mm}^2$

Maximum stirrup spacing - $s_{max} = \min(0.75 \cdot d; 300\ \mathrm{mm}) = 300\ \mathrm{mm}$

Provided stirrup spacing - $s = s_{max} = 300\ \mathrm{mm}$

Provided shear reinforcement area - $A_{sw} = n_w \cdot A_{sw1} \cdot \frac{1\ \mathrm{m}}{s} = 188.5\ \mathrm{mm}^2$ /m

Reinforcement ratio - $\rho_w = \frac{A_{sw}}{s \cdot b} = 0.00251$

$\rho_{w\_min} = \frac{0.08 \cdot \sqrt{\frac{f_{ck}}{\mathrm{MPa}}} \cdot \mathrm{MPa}}{f_{yk}} = 0.000716 < \rho_w = 0.00251$