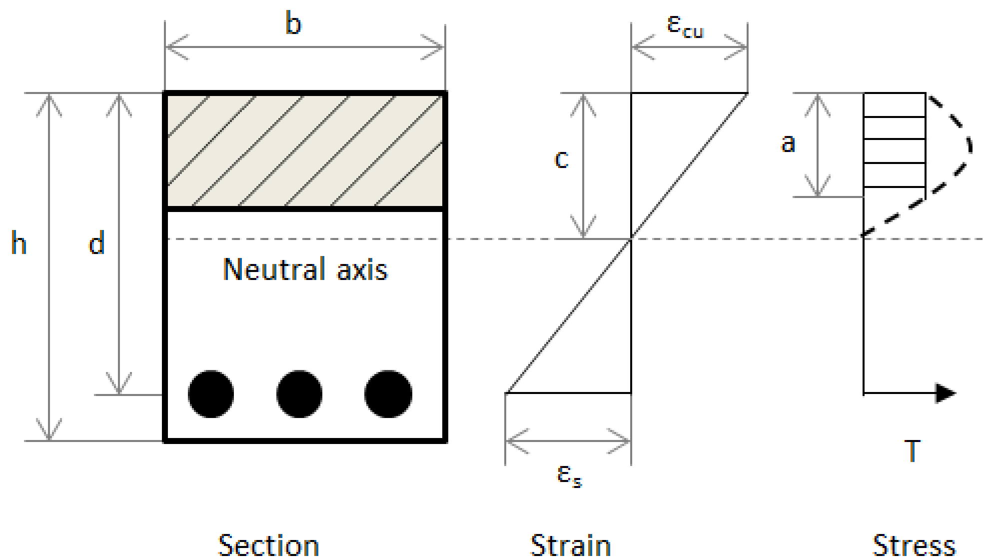
Singly Reinforced Concrete Beam

This applications analyses a singly reinforced concrete beam according to ACI 318-19.

A singly reinforced concrete beam is only reinforced in the tension zone



Parameters

Compressive strength of concrete	$f_c := 25\ \text{MPa}$
Yield strength of reinforcement	$f_y := 390\ \text{MPa}$
Ultimate compressive strain of concrete	$\epsilon_{cu} := 0.003$
Length of beam	$L := 8\ \text{m}$
Height of beam	$h := 500\ \text{mm}$
Width of beam	$b := 300\ \text{mm}$
Effective depth from top of reinforced concrete beam to the centroid of the tensile steel. One row.	$d := h - 90\ \text{mm}$

Live load $LL := 10\ kN \cdot m^{-1}$

Dead load $DL := 8\ kN \cdot m^{-1}$

Analysis

Load combination $W_u := 1.2 \cdot DL + 1.6 \cdot LL = 25.600\ \frac{kN}{m}$

Factored moment for simply supported beam $M_{max} := \frac{W_u \cdot L^2}{8} = 204.800\ kN\ m$

Coefficient for determing stress block height based on concrete strength fc

$$\beta_1 := \begin{cases} 0.85 & f_c \le 28\ MPa \\ 0.85 - 0.05 \cdot \frac{(f_c - 28\ MPa)}{7\ MPa} & 28\ MPa < f_c \le 55\ MPa \\ 0.65 & \text{otherwise} \end{cases}$$

$\beta_1 = 0.850$

Concrete beam design ratio $R_n := \frac{M_{max}}{0.9 \cdot b \cdot d^2} = 4.512 \times 10^6\ Pa$

Reinforcement ratio in concrete beam design As/(db*d) $\rho_{min} := \max\left(\frac{0.25 \cdot \sqrt{f_c \cdot MPa}}{f_y}, \frac{1.4\ MPa}{f_y}\right) = 0.004$

Balanced reinforment ratio $\rho_b := \beta_1 \cdot 0.85 \cdot \frac{f_c}{f_y} \cdot \left(\frac{600\ MPa}{600\ MPa + f_y}\right) = 0.028$

Maximum tensile reinforcement ratio $\rho_{max} := 0.75 \cdot \rho_b = 0.021$

Reinforcement ratio $\rho := 0.85 \cdot \frac{f_c}{f_y} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot R_n}{0.85 \cdot f_c}}\right) = 0.013$

$$\text{beam\_section} := \begin{cases} \text{"Enough section"} & \rho_{min} \le \rho \le \rho_{max} \\ \text{"Enlarge section"} & \text{otherwise} \end{cases}$$

beam_section = "Enough section"

Area of steel reinforcement (tensile reinforcement)	$A_{sreq} := \rho \cdot b \cdot d = 1.619 \times 10^3 \, mm^2$
Rebar diameter	$d_b := 18 \, mm$
Area of rebar	$A_d := \frac{\pi \cdot d_b^{\,2}}{4} = 254.469 \, mm^2$
Number of rebars	$n := ceil\left(\frac{A_{sreq}}{A_d}\right) = 7$
Effective area of steel reinforcement	$A_{spro} := n \cdot A_d = 1.781 \times 10^3 \, mm^2$
Height of stress block	$a := \frac{A_{spro} \cdot f_y}{0.85 \cdot f_c \cdot b} = 0.109 \, m$
Depth of the neutral axis	$c := \frac{a}{\beta_1} = 0.128 \, m$
Strain in the steel	$\epsilon_t := \frac{d - c}{c} \cdot \epsilon_{cu} = 0.007$
Strength reduction factor (0.9 for section to be tension controled in flexure)	$\phi := \begin{cases} 0.9 & \epsilon_t \geq 0.005 \\ 0.65 & \epsilon_t \leq 0.002 \\ 0.65 \cdot \left(\epsilon_t - 0.002 \cdot \frac{250}{3}\right) & \text{otherwise} \end{cases}$
	$\phi = 0.900$
Check moment capacity	$M_n := A_{spro} \cdot f_y \cdot \left(d - \frac{a}{2}\right)$
Nominal moment strength	$M_n = 2.470 \, 10^5 \, N \, m$
	$\phi M_n := \phi \cdot M_n = 222.278 \, kN \, m$
	$Section := \begin{cases} \text{"Pass"} & M_{max} \leq \phi M_n \\ \text{"Fail"} & \text{otherwise} \end{cases}$
	$Section = \text{"Pass"}$