Design of Double Reinforced Rectangular Beam Sections

(Design of DRRS)

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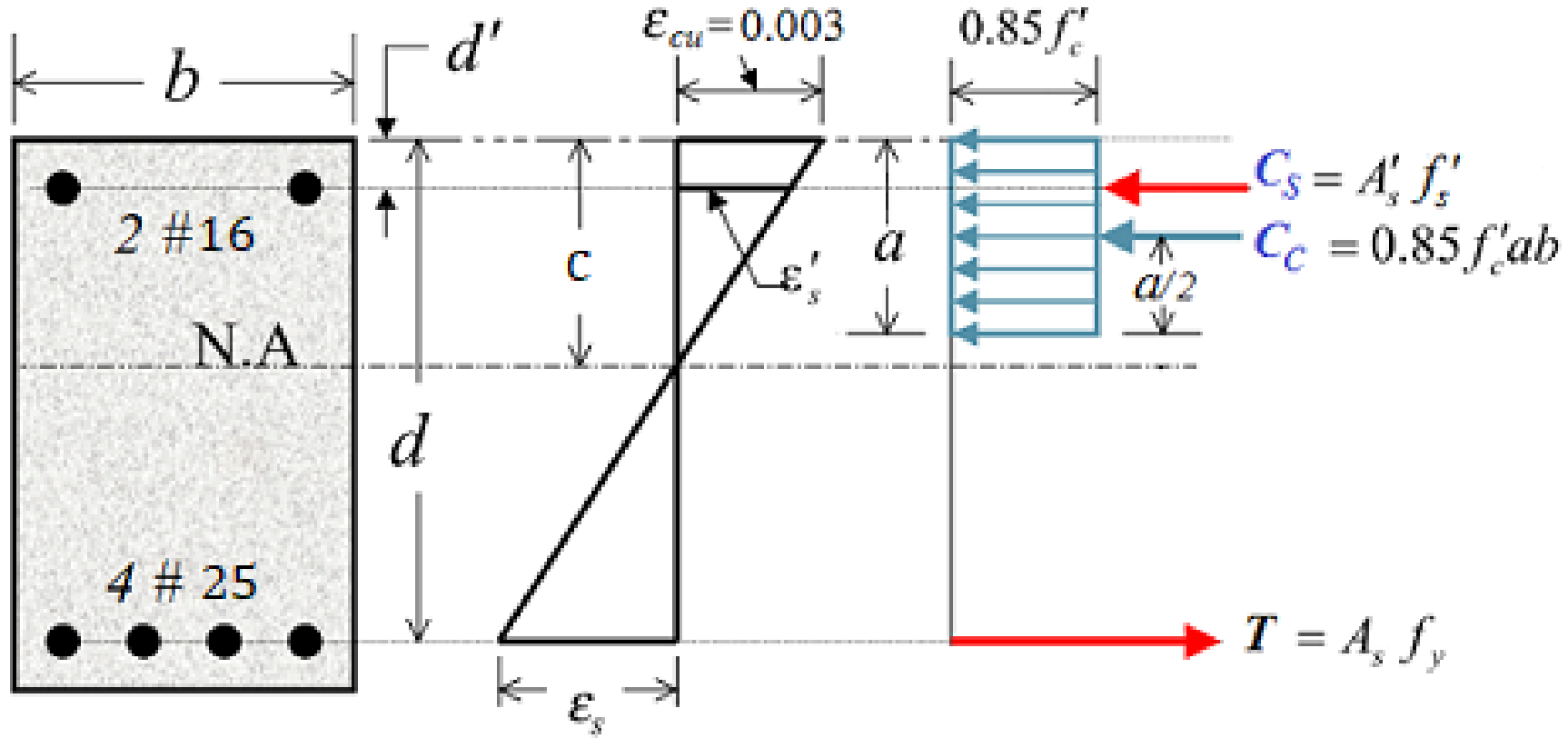


(a) Cross Section (b) Strain Diagram (c) Stress Diagram

$$A_s f_y = 0.85 f'_c \beta_1 c b + A'_s f'_s$$

$$\rho_{max} = \left(\frac{3}{8}\right)\frac{\beta_1}{m}\left(\frac{d_t}{d}\right)$$

$$M_{n(max)} = \rho_{max}\, f_y b d^2 \left(1 - \frac{1}{2}\rho_{max} m\right)$$

$$M_{nmax} \geq \frac{M_u}{\emptyset}$$

Yes → SRRS

No → DRRS

$$M_n = M_{n1} + M_{n2}$$

ρ_{start}

$$\rho_{start} = \left(\frac{3}{10}\right)\frac{\beta_1}{m}\left(\frac{d_t}{d}\right) \Rightarrow As_1 = \rho_{start}\, b\, d$$

$$M_{n1} = \rho_{start}\, f_y b d^2 \left(1 - \frac{1}{2}\rho_{start} m\right)$$

$$M_{n2} = \frac{M_u}{\emptyset} - M_{n1}$$

$$M_{n2} = A_{s2} f_y (d - d')$$

$$A'_s = As_2 \times \frac{f_y}{f'_s}$$

$$M_n = M_{n1} + M_{n2}$$

$$a = \rho\, m\, d$$

$$a_{start} = \rho_{start}\, m\, d$$

$$c_{start} = \frac{a_{start}}{\beta_1}$$

$$f'_s = 0.003\, E_s \left(\frac{c - d'}{c}\right)$$

Ex1: A beam section is limited to a width b=250mm and a total depth of h=550mm and has to resist a factored moment of 307 kN.m. Calculate the required reinforcement, Given: f'c=21 MPa, fy=350 MPa

Solution:

$$m = \frac{f_y}{0.85\, f_c'} = \frac{350}{0.85 \times 21} = 19.607$$

$$\rho_{max} = \frac{3}{8}\frac{\beta_1}{m}\left(\frac{d_t}{d}\right)$$

$$\rho_{max} = \frac{3}{8} \times \frac{0.85}{19.607}(1) = 0.0162$$

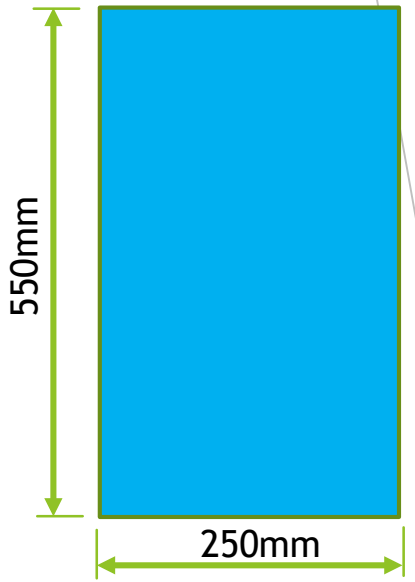
$$M_n = \rho\, f_y\, bd^2\left(1 - \frac{1}{2}\rho m\right)$$

$$d = h - 65 = 550 - 65 = 485mm$$

$$M_n = 0.0162 \times 350 \times 250 \times 485^2\left(1 - \frac{1}{2}0.0162 \times 19.607\right) = 280.293kN.m$$

$$\emptyset M_n = 0.9 \times 280.293 = 252.26 < 307 \quad (Not\ OK)$$

The section should be designed as a DOUBLY REINFORCED SECTION



Assume two layers of tension steel:

$$d = h - 90 = 550 - 90 = 460\ mm$$

$$d_t = h - 65 = 550 - 65 = 485\ mm$$

$$d' = 65\ mm$$

$$\rho_{start} = \frac{3}{10}\frac{\beta 1}{m}\left(\frac{dt}{d}\right)$$

$$\rho_{start} = \frac{3}{10} \times \frac{0.85}{19.607}\left(\frac{485}{460}\right) = 0.0137$$

$$As_1 = \rho_{start}\ b\ d = 0.0137 \times 250 \times 460 = 1575.5\ mm^2$$

$$M_{n1} = \rho\ f_y b d^2\ \left(1 - \frac{1}{2}\rho m\right)$$

$$M_{n1} = 0.0137 \times 350 \times 250 \times 460 \times 460\left(1 - \frac{1}{2}0.0137 \times 19.607\right) = 219.786 kN.m$$

$$M_{n2} = \frac{M_u}{\emptyset} - M_{n1}$$

$$M_{n2} = \frac{307}{0.9} - 219.786 = 121.325\ kN.m$$

$$M_{n2} = A_{s2} f_y (d - d')$$

$$121.325 \times 10^6 = A_{s2} \times 350(460 - 65)$$

$$A_{s2} = 877.577\ mm^2$$

$$As = As_1 + As_2 = 1575.5 + 877.577 = 2453.07\ mm^2$$

$$a = \rho m d = 0.0137 \times 19.607 \times 460 = 123.563 mm$$

$$c = \frac{a}{\beta 1} = \frac{123.563}{0.85} = 145.368 mm$$

$$f_s' = \left[0.003\left(\frac{c - d'}{c}\right)\right] E_s$$

$$f_s' = \left[0.003\left(\frac{145.368 - 65}{145.368}\right)\right] 200000 = 331.716 < f_y$$

$$A_s' = As_2 \times \frac{f_y}{f_s'}$$

$$A_s' = 877.577 \times \frac{350}{331.716} = 926\ mm^2$$

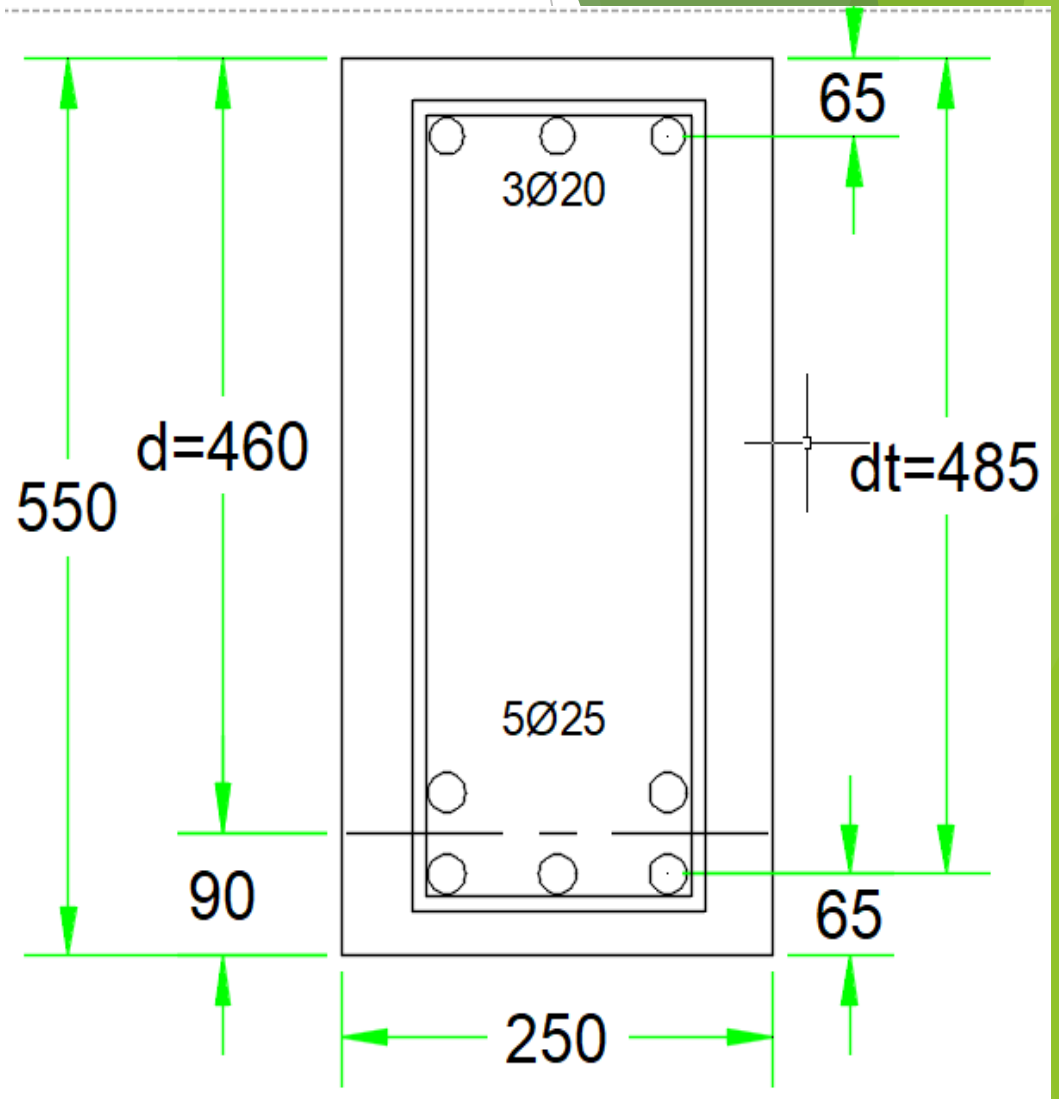
Use: 3Ø20 for compression:

$$A'_s = 3 \times 314 = 942\ mm^2 > 926\ mm^2$$

Use: 5Ø25 for Tension:

$$A_s = 5 \times 490.8 = 2454\ mm^2 \approx 2453.07$$

$$s = \frac{150 - 3 \times 25}{2} = 37.5 > 26.66\ (ok)$$



Thank you…