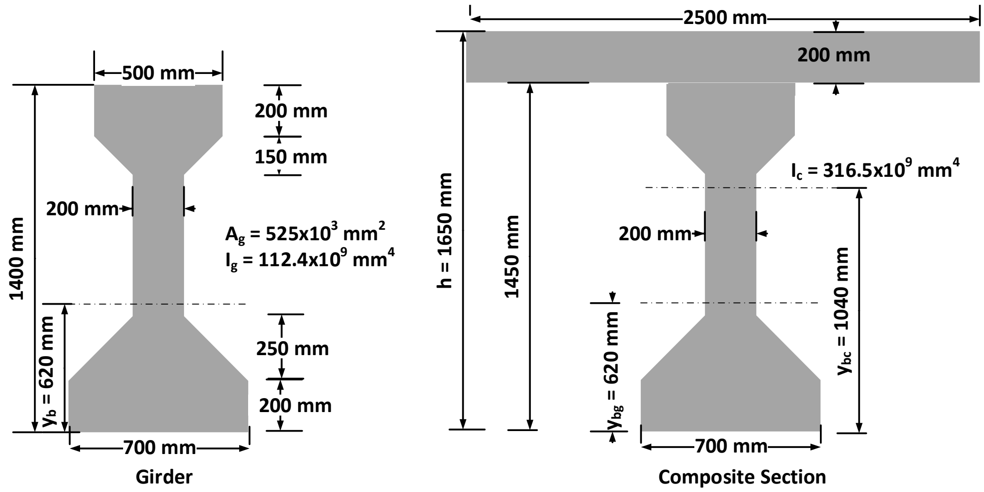
Depending on the figure below; use the following data for all Questions:
Effective length (L) = 27 m
Concrete deck: (f_c') = 28 MPa
Concrete beam: (f_{ci}') = 35 MPa and (f_c') = 42 MPa
Prestressing steel: ($\emptyset_p$) = 12.7 mm, (A_p) = 98.7 mm^2, (f_{py}) = 1674 MPa and (f_{pu}) = 1860 MPa
Losses expected in prestressing = 0.2



Q.1: Determine the required number of strands for the girder to carry (M_{LL+IM}) = 2400 kN.m, (M_{DC1}) = 2700 kN.m, (M_{DC2}) = 275 kN.m, overlay weight (w_{DW}) = 1.6 kN/m and (y_{bp}) = 0.12 m.

Q.2: Check the allowability of stresses in girder section in-service stage of the bridge life.

Q.3: Check the flexural strength of the girder during the bridge life.

<u>Q.1 Sol:</u>

$M_{DW} = w_{DW}.L^2/8 = 1.6\ x\ 27^2/8 = 145.8$ kN.m

$S_{bg} = I_g/y_{bg} = 112.4x10^9/620 = 180.13x10^6$ mm^3

$S_{bcg} = I_c/y_{bcg} = 316.5x10^9/1040.6 = 304.15x10^6$ mm^3

$$f_{bot} = \frac{M_{DC1}}{S_{bg}} + \frac{M_{DC2} + M_{DW} + 0.8M_{(LL+IM)}}{S_{bcg}}$$

$$= \frac{2700}{180.13} + \frac{275 + 145.8 + 0.8\ x\ 2400}{304.15} = 22.69 \text{ MPa}$$

$f_t = 0.50\sqrt{f_c'} = 0.5\ x\ \sqrt{42} = 3.24$ MPa

$f_{c,pe} = f_{bot} - f_t = 22.69 - 3.24 = 19.45$ MPa

$e = y_{bg} - y_{bp} = 620 - 120 = 500$ mm

$$f_{c,pe} = \frac{P_e}{A_g} + \frac{P_e.e_c}{S_{bg}}$$

$$19.45 = \frac{P_e}{525x10^3} + \frac{P_e\ x\ 0.5}{180.13x10^3} \rightarrow P_e = 4155.51 \text{ kN}$$

$f_{pi} = 0.75f_{pu} = 0.75\ x\ 1860 = 1395$ MPa

$P_{i,p} = A_p.f_{pi} = 98.7\ x\ 1395 = 137.68$ kN

$R = 1 - losses = 1 - 0.2 = 0.8$

$P_{e,p} = R.P_{i,p} = 0.8\ x\ 137.86 = 110.29$ kN

$N_p = P_e/P_{e,p} = 4155.51/110.29 = 38$ strands

Q.2 Sol:

$f_c = 0.45f_c' = 0.45\ x\ 42 = 18.9$ MPa

$f_t = 3.24$ MPa

At midspan P_e , $M_{D,nc}$, $M_{D,c}$, M_{DW} and $M_{(LL+IM)}$.

$P_i = N_p.P_{i,p} = 38\ x\ 137.68 = 5231.84$ kN

$P_e = R.P_i = 0.8\ x\ 5231.84 = 4185.47$ kN

$S_{tg} = I_g/y_{tg} = 112.4x10^9/780 = 144.1x10^6$ mm^3

$S_{tcg} = I_c/y_{tcg} = 316.5x10^9/360 = 879.17x10^6$ mm^3

$$f_{top} = -\frac{P_e}{A_g} + \frac{P_e.e}{S_{tg}} - \frac{M_{DC1}}{S_{tg}} - \frac{M_{DC2} + M_{DW} + 0.8M_{(LL+IM)}}{S_{tcg}}$$

$$= -\frac{4185.47}{525} + \frac{4185.47x0.5}{144.1} - \frac{2700}{144.1} - \frac{275 + 145.8 + 0.8x2400}{879.17}$$

$= -7.97 + 14.52 - 18.74 - 2.66 = -14.85$ MPa < 18.9 MPa $\therefore$ OK

$$f_{bot} = -\frac{P_e}{A_g} - \frac{P_e.e}{S_{bg}} + \frac{M_{DC1}}{S_{bg}} + \frac{M_{DC2} + M_{DW} + 0.8M_{(LL+IM)}}{S_{bcg}}$$

$$= -\frac{4185.47}{525} - \frac{4185.47x0.5}{180.13} + \frac{2700}{180.13} + \frac{275 + 145.8 + 0.8x2400}{304.15}$$

$= -7.97 - 11.62 + 14.99 + 7.7 = 3.1$ MPa < 3.24 MPa $\therefore$ OK

At ends P_e load only.

$$f_{top} = -\frac{P_e}{A_g} + \frac{P_e.e}{S_{tg}} = -7.97 + 14.52 = 6.55 \text{ MPa} > 3.24 \text{ MPa} \therefore \text{NOK}$$

$$f_{bot} = -\frac{P_e}{A_g} - \frac{P_e.e}{S_{bg}} = -7.97 - 11.62 = -19.59 \text{ MPa} > 18.9 \text{ MPa} \therefore \text{NOK}$$

Q.3 Sol:

$M_{DC} = M_{DC1} + M_{DC2} = 2700 + 275 = 2975$ kN.m

$M_u = \eta_i[1.25M_{DC} + 1.50M_{DW} + 1.75M_{LL+IM}]$

$= 1.0[1.25x2975 + 1.50x145.8 + 1.75x2400] = 8137.45$ kN.m

$A_{ps} = N_p.A_p = 38x98.7 = 3750.6$ mm^2

$0.5f_{pu} = 0.5x1860 = 930$ MPa

$f_{pe} = R.f_{pi} = 0.8x1395 = 1116$ MPa $> 0.5f_{pu} = 930$ MPa $\therefore$ OK

$d_{ps} = h - y_{bp} = 1650 - 120 = 1530$ mm

$\beta_1 = 0.85 - 0.05(f_c' - 28)/7 = 0.85 - 0.05(42 - 28)/7 = 0.75$

$k = 2(1.04 - f_{py}/f_{pu}) = 2(1.04 - 0.9) = 0.28$

$$c = \frac{A_{ps}.f_{pu}}{0.85f_c'.\beta_1.b_e + k.A_{ps}.f_{pu}/d_{ps}}$$

$$c = \frac{3750.6x1860}{0.85x42x0.75x2500 + 0.28x3750.6x1860/1530}$$

$c = 102.27$ mm < 200 mm $\rightarrow$ rectangular section

$f_{ps} = f_{pu}(1 - k.c/d_{ps}) = 1860(1 - 0.28\ x\ 102.27/1530) = 1825.19\ MPa$

$a = \beta_1.c = 0.75x102.27 = 76.7$ mm

$M_n = A_{ps}.f_{ps}(d_{ps} - a/2) = 3750.6x1825.19(1530 - 76.7/2) = 10210.9$ kN.m

$\phi = 1.0 \rightarrow M_r = 10210.9$ kN.m $> M_u = 8137.45$ kN.m $\therefore$ OK