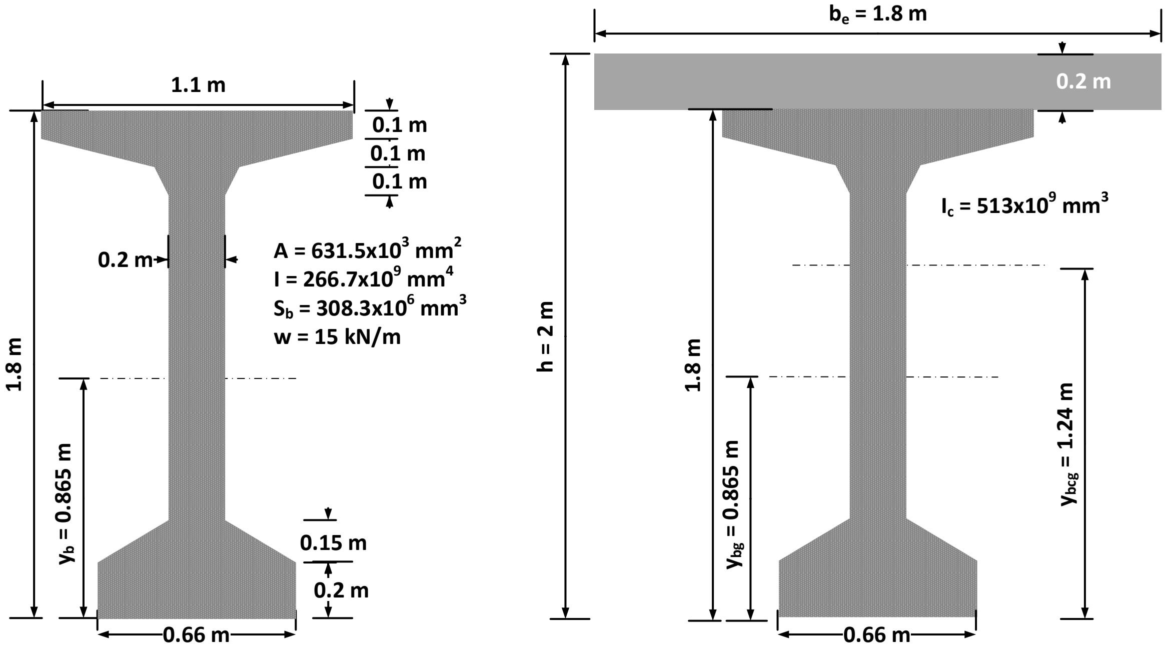
Depending on the figure below; use the following data for all Questions:
Effective length (L) = 30 m
Concrete deck: (f_c') = 28 MPa
Concrete beam: (f_{ci}') = 35 MPa and (f_c') = 42 MPa
Prestressing steel: ($\emptyset_p$) = 12.7 mm, (A_p) = 98.7 mm^2, (f_{py}) = 1674 MPa and (f_{pu}) = 1860 MPa
Losses expected in prestressing = 0.2



Q.1: Determine the required number of strands for the girder to carry (M_{LL+IM}) = 2700 kN.m, (M_{DC1}) = 3000 kN.m, (M_{DC2}) = 360 kN.m and overlay weight (w_{DW}) = 3.2 kN/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.

Q.1 Sol:

$$M_{DW} = w_{DW}.L^2/8 = 3.2\ x\ 30^2/8 = 360 \text{ kN.m}$$

$$S_{bcg} = I_c/y_{bcg} = 513x10^9/1240 = 413.7x10^6 \text{ mm}^3$$

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

$$= \frac{3000}{308.3} + \frac{360 + 360 + 0.8\ x\ 2700}{413.7} = 16.69 \text{ MPa}$$

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

$$f_{c,pe} = f_{bot} - f_t = 16.69 - 3.24 = 13.45 \text{ MPa}$$

Try $y_{bp} = 165$ mm

$$e = y_{bg} - y_{bp} = 865 - 165 = 700 \text{ mm}$$

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

$$13.45 = \frac{P_e}{631.5x10^3} + \frac{P_e\ x\ 0.7}{308.3x10^3}$$

$\rightarrow P_e = 3489.84$ kN

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

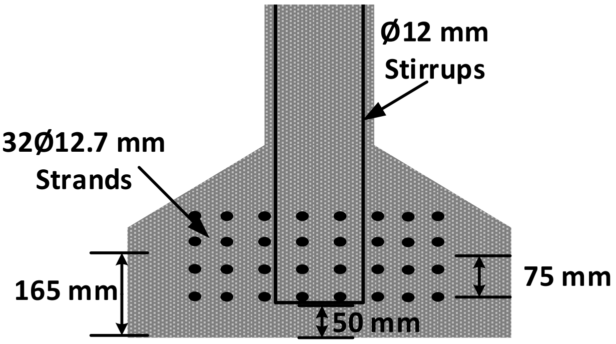
$N_p = P_e / P_{e,p} = 3489.84/110.29 = 32$ strands

Try to use 4 layers of 8 strands in each one with $s = 50$ mm

$y_{bp} = 165$ mm $\rightarrow e_c = 700$ mm $\therefore$ OK

$c_b = 165 - 75 - 12.7/2 - 12 = 71.75$ mm > 50 mm $\therefore$ OK

$c_s = (660 - 8x12.7 - 7x50 - 2x12)/2 = 92.2$ mm > 50 mm $\therefore$ OK



Q.2 Sol:

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

$f_t = 3.24$ MPa

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

$P_i = N_p . P_{i,p} = 32\ x\ 137.68 = 4405.76$ kN

$P_e = R. P_i = 0.8\ x\ 4405.76 = 3524.61$ kN

$S_{tg} = I_g / y_{tg} = 266.7x10^9/935 = 285.24x10^6$ mm^3

$S_{tcg} = I_c / y_{tcg} = 513x10^9/560 = 916.07x10^6$ mm^3

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

$$= -\frac{3524.61}{631.5} + \frac{3524.61x0.7}{285.24} - \frac{2700}{285.24} - \frac{2880}{916.07}$$

$$= -5.58 + 8.65 - 9.47 - 3.14 = -9.54 \text{ MPa} < 18.9 \text{ MPa} \therefore \text{OK}$$

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

$$= -\frac{3524.61}{631.5} - \frac{3524.61x0.7}{308.3} + \frac{2700}{308.3} + \frac{2880}{413.7}$$

$$= -5.58 - 8 + 8.76 + 6.96 = 2.14 \text{ MPa} < 3.24 \text{ MPa} \therefore \text{OK}$$

At ends P_e load only.

$$f_{top} = -\frac{P_e}{A_g} + \frac{P_e . e}{S_{tg}} = -5.58 + 8.65 = 3.07 \text{ MPa} < 3.24 \text{ MPa} \therefore \text{OK}$$

$$f_{bot} = -\frac{P_e}{A_g} - \frac{P_e . e}{S_{bg}} = -5.58 - 8 = -13.58 \text{ MPa} < 18.9 \text{ MPa} \therefore \text{OK}$$

Q.3 Sol:

$M_{DC} = M_{DC1} + M_{DC2} = 3000 + 360 = 3360$ kN.m

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

$= 1.0[1.25\ x\ 3360 + 1.50\ x\ 360 + 1.75\ x\ 2700] = 9465$ kN.m

$A_{ps} = N_p.A_p = 32\ x\ 98.7 = 3158.4$ mm^2

$0.5f_{pu} = 0.5\ x\ 1860 = 930$ MPa

$f_{pe} = R.f_{pi} = 0.8\ x\ 1395 = 1116$ MPa $> 0.5f_{pu} = 930$ MPa $\therefore$ OK

$d_{ps} = h - y_{bp} = 2000 - 165 = 1835$ mm

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

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

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

$$c = \frac{3158.4x1860}{0.85x42x0.75x1800 + 0.28x3158.4x1860/1835}$$

$c = 119.67$ mm < 200 mm $\rightarrow$ rectangular section

$f_{ps} = f_{pu}(1 - k.c/d_{ps}) = 1860(1 - 0.28x119.67/1835) = 1826$ MPa

$a = \beta_1.c = 0.75x119.67 = 89.75$ mm

$M_n = A_{ps}.f_{ps}\left(d_{ps} - a/2\right) = 3158.4x1826(1835 - 89.75/2) = 10324$ kN.m

$\phi = 1.0 \rightarrow M_r = M_n$

$M_r = 10324$ kN.m $> M_u = 9465$ kN.m $\therefore$ OK