Distribution of Strands

Try to use 3 layers of 9 strands in each one with $s = 50\ mm \rightarrow$ check

$e_c = 504\ mm =$ the assumed value $\therefore OK$

$c_b = 70 - 12 - 12.7/2 = 51.65\ mm > 50\ mm \quad \therefore OK$

$c_s = (700 - 9x12.7 - 8x50)/2 = 92.85\ mm > 50\ mm \quad \therefore OK$

Check of Concrete Stresses

At-Release Stage

$f_{ti} = 0.63\sqrt{f'_{ci}} = 0.63\ x\ \sqrt{30} = 3.45\ MPa$

$f_{ci} = 0.6 f'_{ci} = 0.6\ x\ 30 = 18\ MPa$

At midspan P_i and M_g.

$P_i = N_p P_{i,p} = 27\ x\ 137.68 = 3717.36\ kN$

$M_g = w_g L^2/8 = 12.6\ x\ 24^2/8 = 907.2\ kN.m$

$$f_{i,top} = -\frac{P_i}{A_g} + \frac{P_i.e}{S_{tg}} - \frac{M_g}{S_{tg}} = -\frac{3717.36x10^3}{525x10^3} + \frac{3717.36x10^3\ x\ 504}{144.8x10^6} - \frac{907.2x10^6}{144.8x10^6}$$

$$= -7.08 + 12.94 - 6.27 = -0.41\ MPa < 18\ MPa \quad \therefore OK$$

$$f_{i,bot} = -\frac{P_i}{A_g} - \frac{P_i.e}{S_{bg}} + \frac{M_g}{S_{bg}} = -\frac{3717.36x10^3}{525x10^3} - \frac{3717.36x10^3\ x\ 504}{180.07x10^6} + \frac{907.2x10^6}{180.07x10^6}$$

$$= -7.08 - 10.4 + 5.04 = -12.44\ MPa < 18\ MPa \quad \therefore OK$$

At ends P_i load only.

$$f_{i,top} = -\frac{P_i}{A_g} + \frac{P_i.e}{S_{tg}} = -7.08 + 12.94 = 5.86\ MPa > 3.45\ MPa \quad \therefore NOK$$

$\rightarrow$ debond some strands (N_{dp})

$$N_{dp} = \frac{(f_{i,top} - f_{ti})}{f_{i,top}}.N_p = \frac{(5.86 - 3.45)}{5.86} x27 = 11.1 \text{ say } 12 \text{ strands}$$

$$\rightarrow P_{i,eff.} = \frac{(N_p - N_{dp})}{N_p}.P_i = \frac{15}{27}\ x\ 3717.36 = 2065.2\ kN$$

$$f_{i,top} = -\frac{P_{i,eff.}}{A_g} + \frac{P_{i,eff.}.e}{S_{tg}} = -\frac{2065.2x10^3}{525x10^3} + \frac{2065.2x10^3\ x\ 504}{144.8x10^6}$$

$$= -3.93 + 7.19 = 3.26\ MPa < 3.45\ MPa \quad \therefore OK$$

$$f_{i,bot} = -\frac{P_{i,eff.}}{A_g} - \frac{P_{i,eff.}.e}{S_{bg}} = -\frac{2065.2x10^3}{525x10^3} - \frac{2065.2x10^3\ x\ 504}{180.07x10^6}$$

$$= -3.93 - 5.78 = -9.71\ MPa < 18\ MPa \quad \therefore OK$$

Check if tensile reinforcement is needed at top of beam

$f_{ti} = 0.25\sqrt{f'_{ci}} = 0.25\ x\ \sqrt{30} = 1.37\ MPa$ (without bonded reinforcement)

$f_{i,top} = 3.26\ MPa > 1.37\ MPa \ \therefore$ additional bonded reinforcement is needed

from Trigonometric $\rightarrow$ depth of tensile zone $= 362\ mm$

$$T = 200\ x\ 12\ x\frac{0.11}{2} + \frac{200 + 500}{2}\ x\ 150\ x\frac{0.11 + 1.46}{2} + 500\ x\ 200\ x\frac{1.46 + 3.26}{2}$$

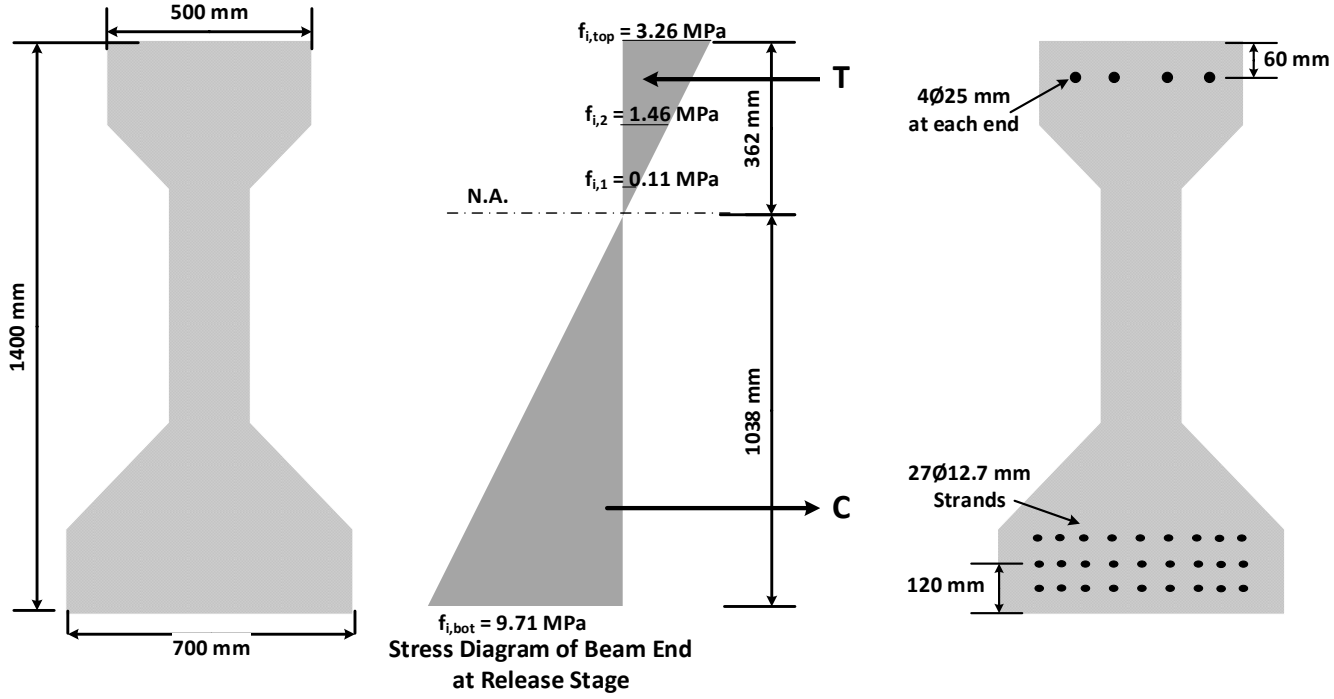
$$= 132 + 41212.5 + 236000 = 277344.5\ N$$

$f_y = 420\ MPa \rightarrow f_s = 170\ MPa$

$A_s = T/f_s = 277344.5/170 = 1631\ mm^2$

$\emptyset_b = 25\ mm \rightarrow A_b = 490.87\ mm^2$

$N_b = A_s/A_b = 1631/490.87 = 3.32$ say 4 bars



In-Service Stage

$f_c = 0.45 f_c' = 0.45\ x\ 35 = 15.75\ MPa$

$f_t = 0.50\sqrt{f_c'} = 0.5\ x\ \sqrt{35} = 2.96\ MPa$

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

$P_e = R.P_i = 0.8\ x\ 3717.36 = 2973.89\ kN$

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

$$= -\frac{2973.89}{525} + \frac{2973.89\ x\ 0.504}{144.8} - \frac{1920.24}{144.8} - \frac{180 + 115.2 + 0.8x1955.35}{880.11}$$

$$= -5.66 + 10.35 - 13.26 - 2.11 = -10.68\ MPa < 15.75\ MPa \quad \therefore OK$$

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

$$= -\frac{2973.89}{525} - \frac{2973.89\ x\ 0.504}{180.07} + \frac{1920.24}{180.07} + \frac{180 + 115.2 + 0.8x1955.35}{303.97}$$

$$= -5.66 - 8.37 + 10.66 + 6.12 = 2.75\ MPa < 2.96\ MPa \quad \therefore OK$$

At ends P_e load only.

$\because P_e < P_i \rightarrow P_{e,eff.} < P_{i,eff.} \quad \therefore$ no need to check