Check of Flexural Strength

Strength I limit State (Factored Moments):

$M_{DC} = M_{DC1} + M_{DC2} = 1920.24 + 180 = 2100.24\ kN.m$

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

$= 1.0[1.25\ x\ 2100.24 + 1.50\ x115.2 + 1.75\ x\ 1955.35] \cong 6220\ kN.m$

$A_{ps} = N_p.A_p = 27\ x\ 98.7 = 2664.9\ mm^2$

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

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

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

$\beta_1 = 0.85 - 0.05(f'_c - 28)/7 = 0.85 - 0.05(35 - 28)/7 = 0.8$

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

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

$$c = \frac{2664.9\ x\ 1860}{0.85\ x\ 35\ x\ 0.8\ x\ 2146.6 + 0.28\ x\ 2664.9\ x\ 1860/1530}$$

$c = 95.33\ mm < 200\ mm \rightarrow$ rectangular section

$f_{ps} = f_{pu}(1 - k.c/d_{ps}) = 1860(1 - 0.28\ x\ 95.33/1530) = 1827.55\ MPa$

$a = \beta_1.c = 0.8\ x\ 95.33 = 76.26\ mm$

$M_n = A_{ps}.f_{ps}(d_{ps} - a/2) = 2664.9\ x\ 1827.55(1530 - 76.26/2) = 7265.76\ kN.m$

$\phi = 1.0 \rightarrow M_r = M_n$

$M_r = 7265.76\ kN.m > M_u = 6220\ kN.m\quad \therefore OK$

Check of Minimum Reinforcement

$f_r = 0.63\sqrt{f'_c} = 0.63\ x\ \sqrt{35} = 3.73\ MPa$

$P_e = A_{ps}.f_{pe} = 2664.9\ x1116 = 2974\ kN$

$$f_{c,pe} = \frac{P_e}{A_g} + \frac{P_e.e_c}{S_{bg}} = \frac{2974x10^3}{525x10^3} + \frac{2974x10^3x504}{180.07x10^6} = 13.99\ MPa$$

$M_{cr} = (f_r + f_{c,pe} - M_{D,nc}/S_{bg})S_{bcg}$

$= (3.73 + 13.99 - 1920.24/180.07)\ x\ 303.97x10^6 = 2144.85\ kN.m$

$M_{cr} \geq f_r.S_{bcg} = 3.73\ x\ 303.97x10^6 = 1133.81\ kN.m\ \therefore OK$

$1.2M_{cr} = 1.2\ x\ 2144.85 = 2573.82\ kN/m$

$1.33M_u = 1.33\ x\ 6220 = 8272.6\ kN.m > 1.2M_{cr}\ \therefore OK$

$M_r = 7265.76\ kN.m > 1.2M_{cr} = 2573.82\ kN.m\quad \therefore OK$

Design of Shear

$\because A_s = 0 \rightarrow d_e = d_{ps} = 1530\ mm$

$d_v = d_{ps} - a/2 = 1530 - 76.26/2 = 1453.74\ mm\quad \leftarrow$ governs

$\geq 0.9d_e = 0.9\ x\ 1530 = 1377\ mm$

$\geq 0.72h = 0.72\ x\ 1650 = 1188\ mm$

$x = d_v + 0.5w_b = 1453.74 + 150 = 1603.74\ mm \cong 1.6\ m$

$V_{DC} = w_{DC}(0.5L - x) = 29.17(0.5\ x\ 24 - 1.6) = 303.37\ kN$

$V_{DW} = w_{DW}(0.5L - x) = 1.6(10.4) = 16.64\ kN$

$V_{Ln} = w_{Ln}(0.5L - x) = 9.3(10.4) = 96.72\ kN$

$V_{Tr} = 264.81\ kN$

Live Load Distribution Factor for Shear:

$DFV_{si} = 0.36 + S/7600$

$= 0.36 + 2.4/7.6 = 0.676$

$DFV_{mi} = 0.2 + S/3600 - (S/10700)^2$

$= 0.2 + 2.4/3.6 - (2.4/10.7)^2 = 0.817$

$\rightarrow DFV_{int} = 0.817$

$V_{LL+IM} = DFV_{int}[(1 + IM)V_{Tr} + V_{Ln}]$

$= 0.817[1.33\ x\ 246.81 + 96.72] = 347.2\ kN$

Strength I limit State (Factored Shear):

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

$= 1.0[1.25\ x\ 303.37 + 1.5\ x\ 16.64 + 1.75\ x\ 347.2] = 1011.8\ kN$

Check the adequacy of the section for shear resistance:

$V_n = 0.25f_c'.b_v.d_v = 0.25\ x\ 35\ x\ 200\ x\ 1453.74 = 2544\ kN$

$\phi V_n = 0.9\ x\ 2544 = 2289.6\ kN > V_u = 1011.8\ kN \rightarrow$ the section is adequate

$V_c = 0.166\sqrt{f_c'}.b_v.d_v = 0.166\ x\ \sqrt{35}\ x\ 200\ x\ 1453.74 = 285.53\ kN$

$\phi V_c = 0.9\ x\ 285.53 = 257\ kN < V_u \rightarrow A_v$ is required

$V_s = (V_u - \phi V_c)/\phi = (1011.8 - 257)/0.9 = 838.67\ kN$

Details of shear reinforcement:

$v_u = V_u/\emptyset b_v.d_v = 1011.8x10^3/(0.9\ x\ 200\ x\ 1453.74) = 3.867\ MPa$

$0.125f_c' = 0.125\ x\ 35 = 4.375\ MPa > v_u$

$s_{max} = 0.8d_v = 0.8\ x\ 1453.74 = 1163\ mm$

$\leq 600\ mm \qquad \leftarrow$ governs

$\emptyset_v = 12\ mm \rightarrow A_v = 226\ mm^2$

$s = A_v.f_y.d_v/V_s = 226\ x\ 420\ x\ 1453.74/(838.67x10^3) = 164.53\ mm$

use Ø12 @ 150 mm o.c. stirrups