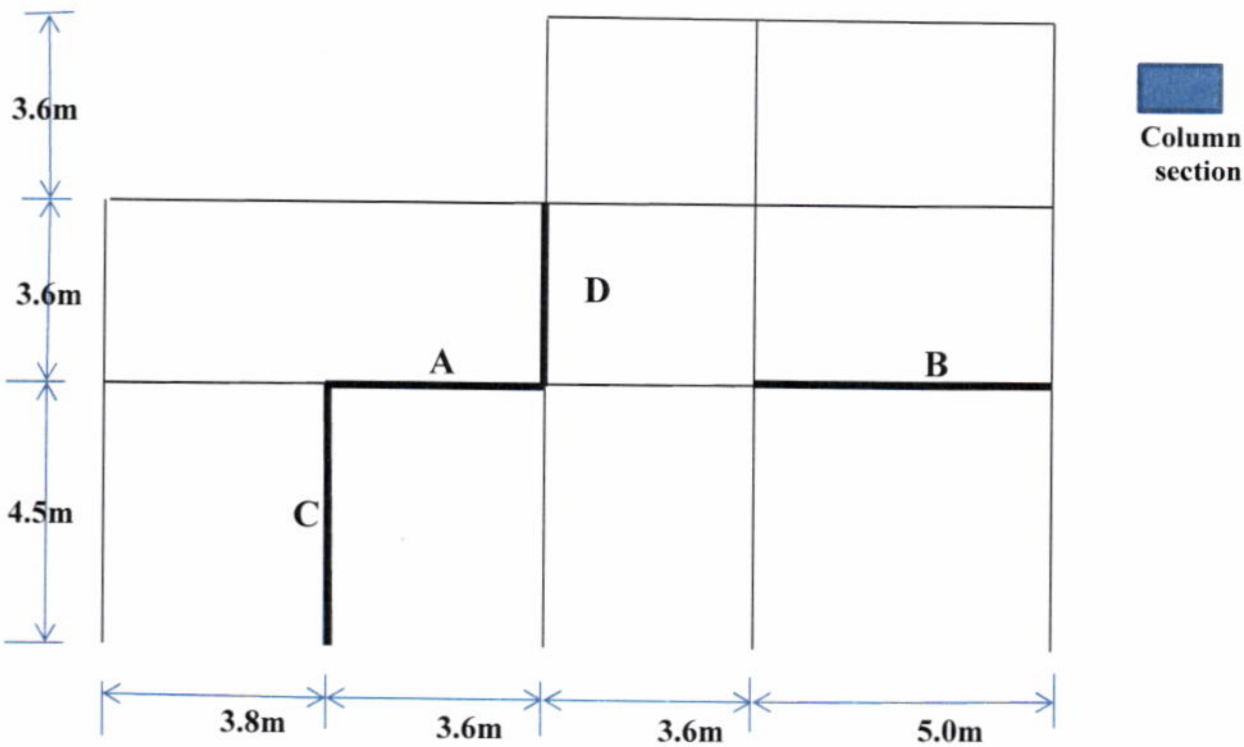
University Of Technology
Building and Construction Eng. Dept.
Final Exam –2013/2014

Subject : Structural Design | Class: Fourth
Branch : Structural | Time : 3 Hours
Examiners :Dr.Faidhi AlKhazraji | Date:9th Jun.2014

Open Book Exam -------- Answer Four Question Including Q2 & Q4

Use: $fc' = 32Mpa$, $f_y = 420Mpa$

Q1) By using sub frame analysis method and alternate pattern loading find the maximum moment end reaction for beams A & B in the precast concrete frame shown in figure. Moreover find the maximum end moments for the columns C & D. Assume column C having pinned support and the beam column connections are pinned. Beams sections are 300x500mm and columns are rectangular 200x400mm. The distance from the edge of the column to the center of beam end reaction is 110mm. Applied: D.L.=44kN/m and L.L.=37kN/m. **20%**

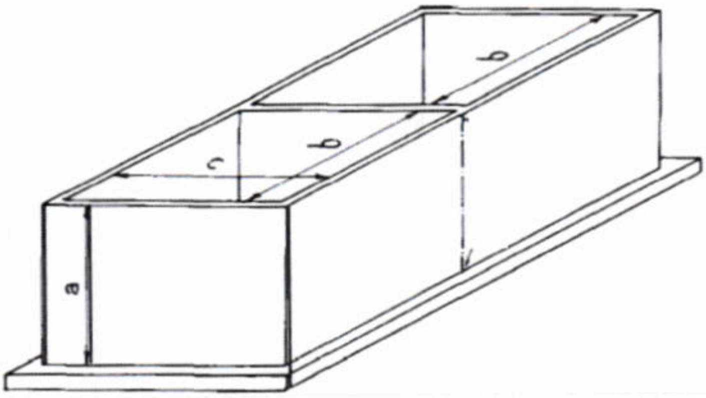


Q2) By using the LRFD method find if it is adequate to use rebar (Ø16@175mm c/c) for the longitudinal main reinforcement parallel to the traffic direction for the 250mm thick deck slab. If not redesign it. The deck slab having span length 5.5m and width 7.5m and supported on two 300x600mm concrete beams. Assume the wearing surface is made of 7cm thick asphalt of 23kn/m³ density and the live load according to AASHTO is HS15. Use Ɣconcrete=24kN/m³.

25%

Q3) A column Corbel of overall depth h=600mm, width b=400mm, effective depth d=530mm and shear span a_V=120mm. Considered to carry factored shear force Vu=540kN and factored horizontal tensile force Nu=200kN. Assuming the concrete surface of the Corbel is intentionally roughened according to ACI-11.6.9. Required to check the code limitations of the Corbel and design the steel area according to ACI-318M.08 with detailed drawing. Use Rebar: Ø20mm for reinforcement and Ø10mm for stirrups. **20%**

Q4)



A rectangular concrete water Tank of two cells having the dimensions a=5m, b=10m and c=5m with wall thickness t=320mm. The Tank has no cover at the top and hinged support at the base.
Required:
1- Flexural reinforcement for the absolute maximum horizontal and vertical moments (for both faces) for the long outer wall. Draw section in the wall showing the reinforcement details. (Hint: write the coefficient moment table)
2- Design reinforcement following the BS8007, assuming the maximum allowable crack width is 0.2mm. Use, T_1=35°C, T_2=60°C, α=12x10^{-6}m/m/°C, Rebar Ø20mm (A_b=314mm^2) and Cover=50mm. **35%**

Q5) Circular water Tank of dimensions D=20m, H=6m and wall thickness t=0.36m. The Tank has no cover and hinged support at the base. Required:

1- Design the horizontal tension reinforcement using rebar Ø16mm (A_b=201mm^2).
2- Check for crack stress.
3- Check for shear force.
Use: E_s=200000Mpa, E_c=26587Mpa and c=0.0003

20%

Q1

$W_{u\,max.} = 1.2\,DL + 1.6\,LL$
$= 1.2 \times 44 + 1.6 \times 37 = 112\ kN/m$

$W_{u\,min.} = 1.2\,DL = 1.2 \times 44 = 52.8\ kN/m$

$e = \frac{h}{2} + 110mm = 200 + 110 = 310mm$

Beam A: $M_{max} = 112 \times \frac{[3.6 - (2 \times 0.31)]^2}{8} = 124.3\ kN$

Beam end reactions $= 112 \times \frac{3.6}{2} = 201.6\ kN$

Beam B: $M_{max} = 112 \times \frac{[5 - (2 \times 0.31)]^2}{8} = 268.6\ kN.m$

Beam end reactions $= 112 \times \frac{5}{2} = 280\ kN$

Column C: $R_1 = \frac{112 \times 3.8}{2} = 212.8\ kN$

$R_2 = \frac{52.8 \times 3.6}{2} = 95\ kN$

$M_{col.\,upper} = (212.8 - 95) \times 0.31 \times \frac{0.75 \times (\frac{EI}{h})_c}{0.75 \times (\frac{EI}{h})_c}$

$= 36.51\ kN.m$

$M_{col.\,lower}$ = Zero (Pin)

Column D: $R_1 = \frac{112 \times (3.6 + 3.8)}{2} = 414.4\ kN$

$R_2 = \frac{52.8 \times 3.6}{2} = 95\ kN$

$M_{col.\,upper} = (414.4 - 95) \times 0.31 \times \frac{(\frac{EI}{h})_D}{(\frac{EI}{h})_D + (\frac{EI}{h})_i}$

$M_{col.upper} = (414.4 - 95) \times 0.31 \times \left(\frac{3.6}{3.6+3.6}\right)$ $\nearrow \frac{1}{2}$

$= 49.5 \text{ kN.m}$

$M_{col lower}$: $R_1 = \frac{112 \times 3.6}{2} = 201.6 \text{ kN}$

$R_2 = \frac{52.8 \times 3.6}{2} = 95 \text{ kN}$

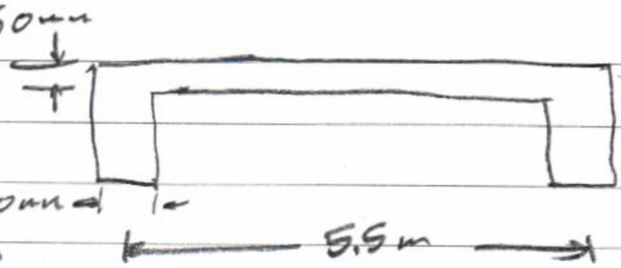
$$M_{col lower} = (201.6 - 95) \times 0.31 \times \frac{\left(\frac{EI}{h}\right)_D}{\left(\frac{EI}{h}\right)_D + \left(\frac{EI}{h}\right)_i}$$

$$= 33.034 \times \frac{\frac{1}{3.6}}{\frac{1}{3.6} + \frac{1}{4.5}}$$

$$= 33.034 \times \frac{0.278}{0.278 + 0.222}$$

$$= 18.4 \text{ kN.m}$$

Q2 $l_{eff} = 5.5m$



$l_{clear} = 5.5 - 0.3 = 5.2m$

or $l_{eff} = 5.2 + 0.25 = 5.45m$

∴ use $l_{eff} = 5.45m$

D.L: self wt. = $0.25 \times 24 = 6\ kN/m^2$

$$M_{DC} = \frac{6 \times (5.45)^2}{8} = 22.3\ kN.m/m$$

Wearing asphalt = $0.07 \times 23 = 1.61\ kN/m^2$

$$M_{DW} = \frac{1.61 \times (5.45)^2}{8} = 6\ kN.m/m$$

L.L: load is HS15

The load on each rear wheel is $\frac{24000}{2}$ lb

∴ L.L (P15) = 12000 lb

$$E = 4 + 0.06S = 4 + 0.06 \times \frac{5.45}{0.3048} = 5.073\ ft < 7\ ft \therefore ok$$

∴ use E = 5.073 ft

The load on a unit width of slab = $\frac{12000}{5.073} = 2365.464$ lb/ft

$$M_L = \frac{P.S}{4} = \frac{2365.464 \times \frac{5.45}{0.3048}}{4} = 10574\ lb.ft/ft$$

$$M_L = 10574 \times \frac{4.448}{1000} = 47\ kN.m/m$$

or $M_L = 900S \times \frac{3}{4} = 900 \times \frac{5.45}{0.3048} \times \frac{3}{4} = 12069.4$ lb.ft/ft

∴ use $M_L = 12069.4 \times \frac{4.448}{1000} = 53.7\ kN.m/m$

$$I = \frac{50}{S + 125} = \frac{50}{\frac{5.45}{0.3048} + 125} = 0.35 > 0.3$$

$\therefore$ Use $I = 0.3$

$\therefore M_{L.L}$ with Impact $= 53.7 \times 1.3 = 69.8$ kN.m/m

$\therefore M_T = 1.25 M_{DC} + 1.5 M_{DW} + 1.75 M_{L.L}$

$= 1.25 \times 22.3 + 1.5 \times 6 + 1.75 \times 69.8$

$= \underline{159 \text{ kN.m/m}}$

$d_{eff} = 250 - 25 - \frac{16}{2} = 217$ mm

$R_u = \frac{M_T}{\phi b d^2} = \frac{159 \times 10^6}{0.9 \times 10^3 (217)^2} = 3.751$

$m = \frac{f_y}{0.85 f'_c} = \frac{420}{0.85 \times 32} = 15.441$

$\rho = \frac{1}{15.441} \left[1 - \sqrt{1 - \frac{2 \times 3.751 \times 15.441}{420}} \right] = 0.00965$

$A_{s\,req.} = 0.00965 \times 1000 \times 217 = 2094$ mm²/m

$A_{s\,prov.} = \frac{1000}{175} \times 201 = 1148.6$ mm²/m

Not O.K $\therefore$ Change the design of reinf.

No. of bars $= \frac{2094}{201} = 10.418$

Spacing $= \frac{1000}{10.418} = 96$ mm

$\therefore$ Use $\phi 16$ @ 90 mm c/c

Requirement for AASHTO

minimum spacing for Rebar $> 1.5 d_b = 1.5 \times 16 = 24$ mm

> 1.5 max. agg size $=$
$1.5 \times 25 = 37.5$

> 38 mm (control)

$\therefore$ using 90mm > 38mm $\therefore$ o.k

maximum spacing for Rebar $\leq 1.5 h = 1.5 \times 250$
$= 375$ mm

≤ 450mm

using 90mm < 375mm $\therefore$ o.k

$\therefore$ **Use $\phi 16$ @ 90mm c/c**

Q3 Check the Corbel according to ACI Code:

Check dimensions:

$\frac{a_v}{d} = \frac{120}{530} = 0.226 < 1 \quad \therefore$ o.k

$\frac{N_{uc}}{V_u} = \frac{200}{540} = 0.37 < 1 \quad \therefore$ o.k

Check shear force applied:

$0.2 f'_c \phi b_w d = 0.2 \times 32 \times 0.75 \times 400 \times 530 \times 10^{-3} = 1017$ kN

$(3.3 + 0.08 f'_c)\phi b_w d = (3.3 + 0.08 \times 32)\, 0.75 \times 400 \times 530$
$= 931.7$ kN

$11 \phi b_w d = 11 \times 0.75 \times 400 \times 530 = 1749$ kN

The smallest is $931.7 >$ applied $V_u = 540$ kN

$\therefore$ The Corbel is accepted according to ACI-Code

Tension reinforcement:

$N_{uc} = 200$ kN $> 0.2 V_u = 108$ kN $\therefore$ use $N_{uc} = 200$ kN

$A_n = N_{uc}/\phi f_y = \frac{200 \times 10^3}{0.75 \times 420} = 635$ mm^2

$A_{vf} = \frac{V_u}{\phi \mu f_y} = \frac{540 \times 10^3}{0.75 \times 1.4 \times 420} = 1225$ mm^2

Flexural Reinforcement:

$M_u = V_u a_v + N_{uc}(h - d)$

$M_u = 540 \times 0.12 + 200(0.6 - 0.53) = 78.8$ kN.m

$R_u = \frac{78.8 \times 10^6}{0.9 \times 400 (530)^2} = 0.78$ MPa

$\rho = \frac{1}{15.44}\left(1 - \sqrt{1 - \frac{2 \times 0.78 \times 15.44}{420}}\right) = 0.001885$

$A_f = 0.001885 \times 400 \times 530 = 400$ mm^2

A_{sc} shall be $\geq (A_f + A_n) = (400 + 635) = 1035$ mm^2

$\geq (\frac{2}{3} A_{vf} + A_n) = (\frac{2}{3} \times 1225 + 635) = 1452$ mm^2

$\geq (0.04 f'_c/f_y) \times bd = 0.04 \frac{32}{420} \times 400 \times 530 = 646$ mm

$\therefore A_{sc} = 1452$ mm^2

Q3/P.1

$No. of\ \phi 20 = \frac{1452}{314} = 4.62$

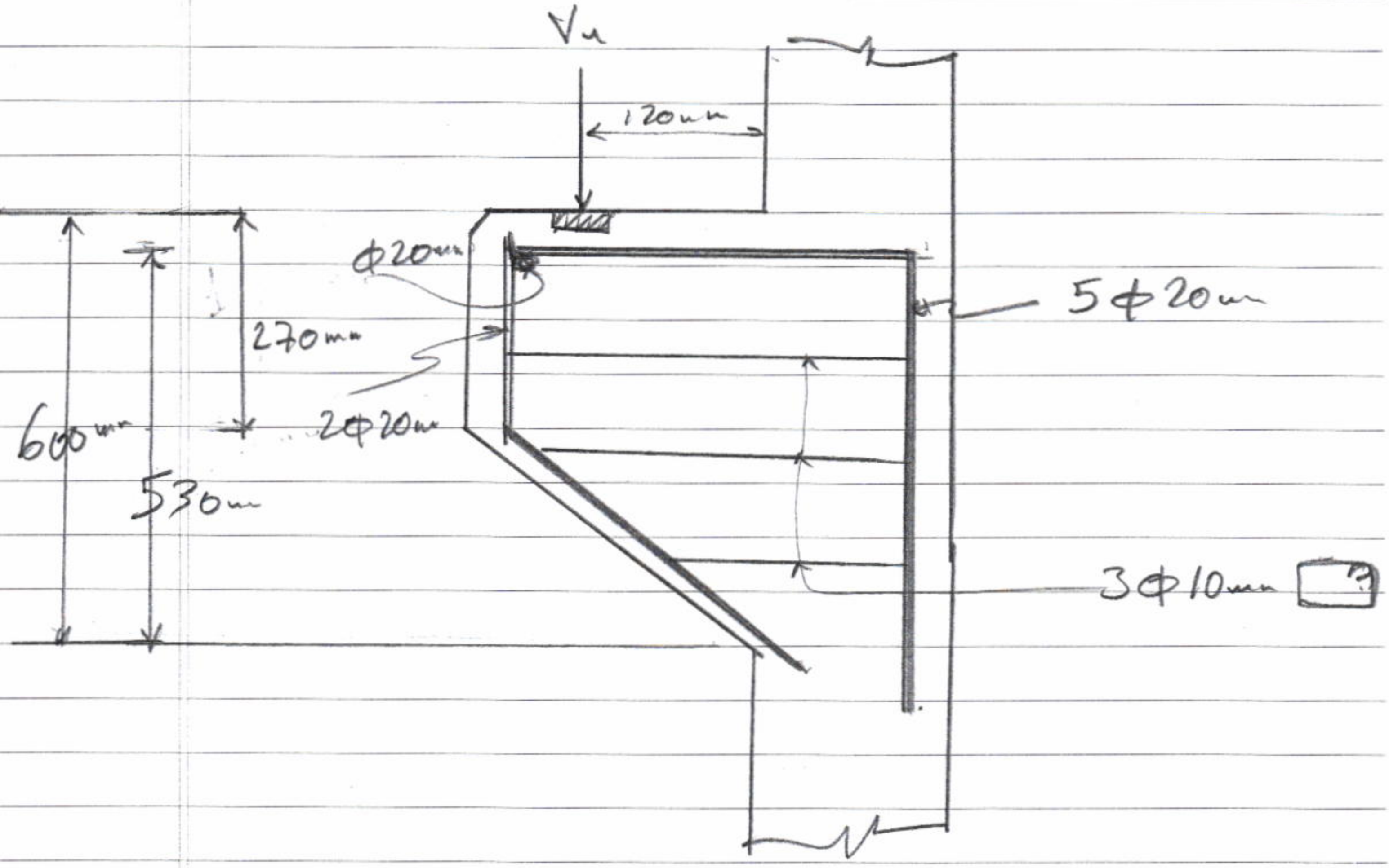
$\therefore$ Use $5\ \phi 20mm$ Primary Reinforcement

Closed stirrups $A_h \geq 0.5(A_{sc} - A_n) = 0.5(1452 - 635)$
$= 409 mm^2$

use $\phi 10 \rightarrow A_h = 79 mm^2$

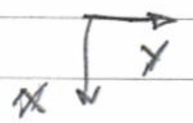
$No.\ of\ layers\ closed\ stirrups = \frac{409}{2 \times 79} = 2.6$

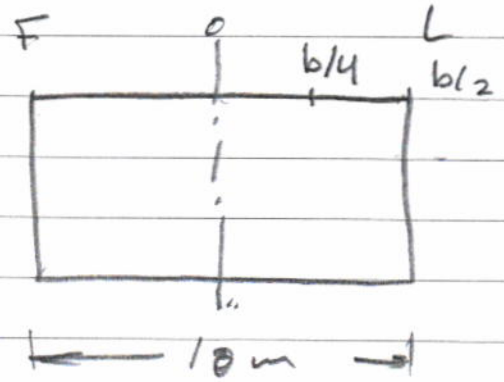
use 3 $\phi 10mm$



(Q4)(1): $b/a = 2$, $c/a = 1$

$d = 320 - 50 - 10$
$d = 260$ mm





Long outer wall mom. coeff.

x/a	Coeff. L : Table-5						Coeff. F / Table-2	
	y = b/2		y = b/4		y = 0		y = b/2	
	M_x	M_y	M_x	M_y	M_x	M_y	M_x	M_y
0	0	−0.058	0	+0.027	0	+0.054	0	−0.091
1/4	−0.012	−0.062	+0.010	+0.027	+0.019	+0.050	−0.019	−0.094
1/2	−0.013	−0.064	+0.024	+0.025	+0.037	+0.042	−0.018	−0.089
3/4	−0.010	−0.051	+0.027	+0.018	+0.037	+0.026	−0.013	−0.065

$W_u = 1.3 \times 1.7 \times 9.8 = 21.7$ kN/m²/m

The largest coeff. moments (−ve & +ve) are:

M_y: −0.094 @ $x/a = \frac{1}{4}$, +0.054 @ $x/a = 0$

M_x: −0.019, +0.037

Design for M_x:

$-ve\ M_{y\,max} = 0.094 \times 21.7 (5)^3 = 255$ kN.m

This moment acts at $x/a = \frac{1}{4}$ find N_u at this level

$N_u = V_u = 0.27\, w\, a^2$

$w = 1.65 \times 1.7 \times 9.8 = 27.5$ kN/m²/m

$\therefore N_u = 0.27 \times 27.5 \times (5)^2 = 185.6$ kN/m

$$R_u = \frac{255 \times 10^6}{0.9 \times 1000 \times (260)^2} = 4.19$$

$$\rho = \frac{1}{15.44}\left(1 - \sqrt{1 - \frac{2 \times 4.19 \times 15.44}{420}}\right) = 0.0109 > \rho_{min}$$

$A_s = 0.0109 \times 1000 \times 260 = 2832$ mm²

For N_u: $A_s = \frac{185.6 \times 10^3}{0.9 \times 420} = 491\ mm^2/m$

required $A_s = 2832 + \frac{491}{2} = 3078\ mm^2/m$

No. of bars $= \frac{3078}{314} = 9.8$

Spacing $= \frac{1000}{9.8} = 102\ mm$

use $\phi 20$ @ 100 mm c/c (Horizontal inner side)

+ve $M_{y\,max} = 0.054 \times 21.7\,(5)^3 = 146.5\ kN.m/m$

$N_u = V_u = 0.08 \times 27.5 \times (5)^2 = 55\ kN/m$

A_s for $N_u = \frac{55000}{0.9 \times 420} = 146\ mm^2/m$

$R_u = \frac{146.5 \times 10^6}{0.9 \times 1000\,(260)^2} = 2.39$

$\rho = \frac{1}{15.44}\left(1 - \sqrt{1 - \frac{2 \times 2.39 \times 15.44}{420}}\right) = 0.005977 / \rho_{min} = 0.003$

$A_s = 0.00597 \times 1000 \times 260 = 1552\ mm^2/m$

required $A_s = 1552 + \frac{146}{2} = 1625\ mm^2/m$

No. of bars $= \frac{1625}{314} = 5.175$

spacing $= \frac{1000}{5.175} = 193\ mm$

use $\phi 20$ @ 190 mm c/c (Horizontal outer side)

Design for M_x:

+ve $M_{x\,max} = 0.037 \times 21.7\,(5)^3 = 100.4\ kN.m/m$

$R_u = \frac{100.4 \times 10^6}{0.9 \times 1000\,(260)^2} = 1.65$

$\rho = \frac{1}{15.44}\left(1 - \sqrt{1 - \frac{2 \times 1.65 \times 15.44}{420}}\right) = 0.004055 > \rho_{min} = 0.003$

$A_s = 0.004055 \times 1000 \times 260 = 1054\ mm^2/m$

No. of bars $= \frac{1054}{314} = 3.36$

spacing $= \frac{1000}{3.36} = 298\ mm$

use $\phi 20$ @ 280 mm c/c (Vertical outer side)

$-ve\ M_{x\,max} = 0.019 \times 21.7 (5)^3 = 51.54\ kNm/m$

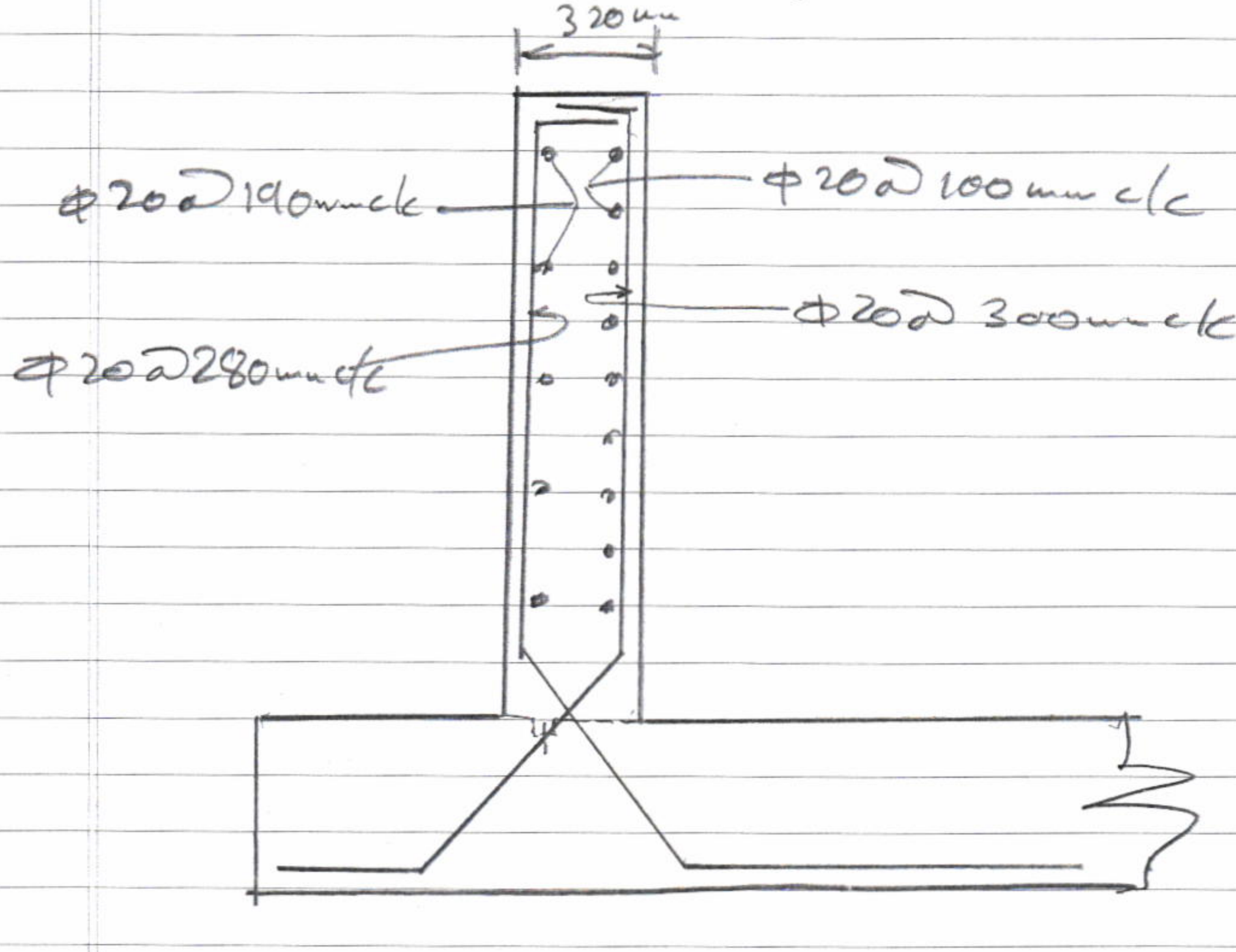
use $\rho_{min} = 0.003$

$A_{s\,min} = 0.003 \times 1000 \times 320 = 960\ mm^2/m$

No. of bars $= \frac{960}{314} = 3.06$

spacing $= \frac{1000}{3.06} = 327\ mm$

use $\phi 20$ @ 300 mm c/c (Vertical inner side)



Q4/P,3

Q4/(2) $0.2 = S_{max} \frac{12\times10^{-6}}{2}(35+60)$

Solve for $S_{max} = 350.9$ mm

$S_{max} = \frac{f_{ct}}{f_b} \times \frac{\phi}{2\rho}$

$350.9 = 0.67 \times \frac{20}{2\rho}$

∴ $\rho = 0.0191$

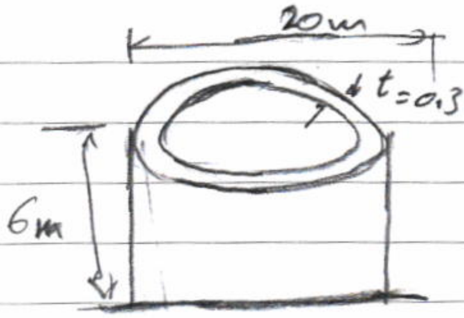
$A_s = 0.0191 \times \frac{320}{2} \times 1000 = 3055\ mm^2/m$

No. of bars $= \frac{3055}{314} = 9.73$

Spacing $= \frac{1000}{9.73} = 103$ mm

∴ Use $\phi 20$ @ 100 mm c/c in both direction and in both faces

Q5 $\frac{H^2}{D.t} = \frac{(6)^2}{20 \times 0.36} = 5$



$W_u = 1.65 \times 1.7 \times 9.8 = 27.5 \ kN/m^3$

$W_u \cdot H \cdot R = 27.5 \times 6 \left(\frac{20}{2}\right)$
$= 1650 \ kN/m$

(1) From Table A-5;
Maximum Tension = $0.617 \times 1650 = 1018.05 \ kN/m$

$A_{s\,req.} = \frac{1018.05 \times 10^3}{0.9 \times 420} = 2693 \ mm^2/m$

$\rho_{actual} = \frac{2693}{360 \times 1000} = 0.0075 > 0.005 \ \therefore$ o.k

No. of bars $= \frac{2693}{2 \times 201} = 6.7$

spacing $= \frac{1000}{6.7} = 149 \ mm$

$\therefore$ use $\phi 16$ @ 140 mm c/c for horizontal reinf.

$A_{s\,prov.} = \frac{2 \times 201 \times 1000}{140} = 2871 \ mm^2/m$

(2) Stress in Concrete $f_c < 0.1 f'_c$

$f_c = [C E_s A_s + T_{max\,unfact.}] / (A_c + n A_s)$

$n = \frac{E_s}{E_c} = \frac{200000}{4700\sqrt{32}} = 7.5$

$f_c = \left[0.0003 \times 200000 \times 2871 + \frac{1018.05 \times 10^3}{1.65 \times 1.7}\right] \times \frac{1}{360 \times 1000 + 7.5 \times 2871}$

$f_c = 1.4 \ MPa < 0.1 \times 32 = 3.2 \ MPa$

$\therefore$ ok

(3) Check for shear : $d = 360 - 50 - \frac{16}{2} = 302\,mm$

$\phi V_c = \phi \frac{\sqrt{f_c'}}{6} bd$

$\phi V = 0.85 \times \frac{\sqrt{32}}{6} \times 1000 \times 302 \times 10^{-3} = 242\,kN$

$W_u = 1 \times 1.7 \times 9.8 = 16.66\ kN/m^3$

$W_u \cdot H^2 = 16.66(6)^2 = 600\ kN/m$

From Table A12 :

$V_u = 0.121 \times 600 = 72.6\ kN/m$

$< \phi V_c$

$\therefore$ o.k

Q5/P.2