Ain Shams University
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Structural Engineering Department
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Foundation Engineering

4th Year Civil-Structural Division

Assignment (4)
PILED FOUNDATIONS

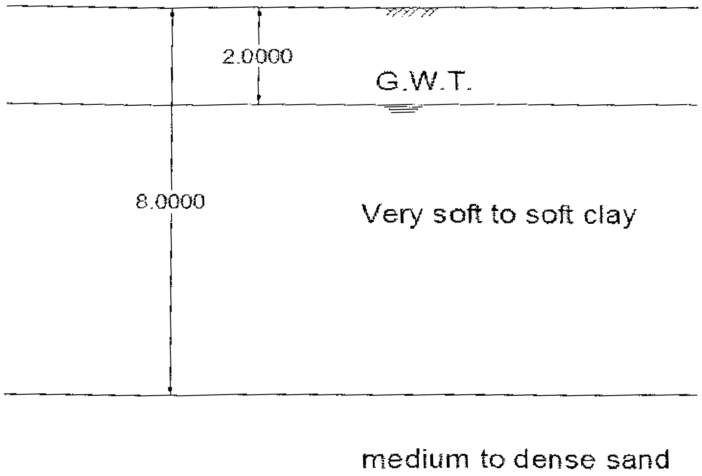
Fall semester- 2015/2016

- Question (2):

Site No. 1:

- Given load=10000KN (large load value).
- Presense of high level of water (6m waterabove bearing layer).

∴Use large diameter bored pile with bentonite slurry.



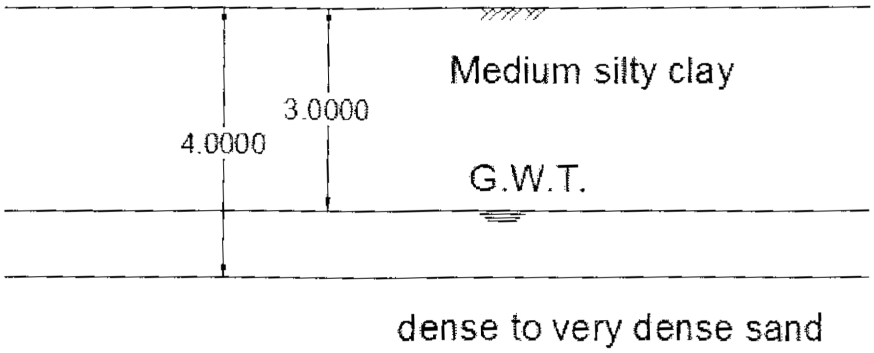
Reasons of choice:

- large diameter: As we have large load value ,so we need large diameter.
- Bored pile: must be used at downtown as we cant use Driven pile.
- Bentonite slurry: Holes must be filled with bentonite slurry to prevent water seepage into it.and also to avoid boiling.

Site No. 2:

- Given load=1000KN : 2500 KN.
- Position: downtown.

∴Use bored pile with bentonite slurry.
or: Use CFA .



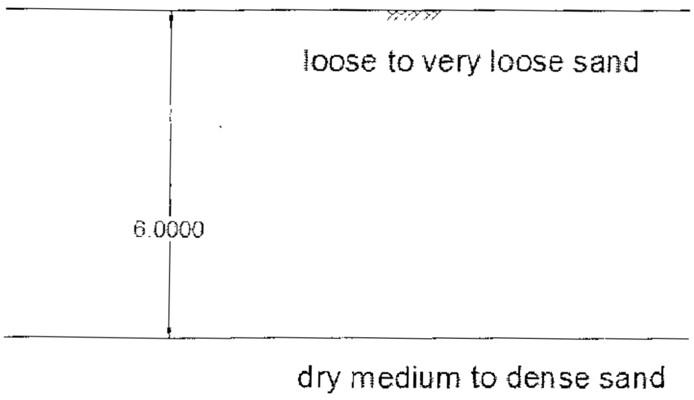
Reasons of choice:

- Bored pile or CFA: must be used at downtown as we cant use Driven pile, and CFA can be used here as the soil is medium clay (no necking occurs) .
- Bentonite slurry: Holes must be filled with bentonite slurry to prevent water seepage into it,and also to avoid boiling.

Site No. 3:

- Given load=1000KN : 2500 KN.
- Position: new Cairo.

∴ Use bored pile with temporary casing.

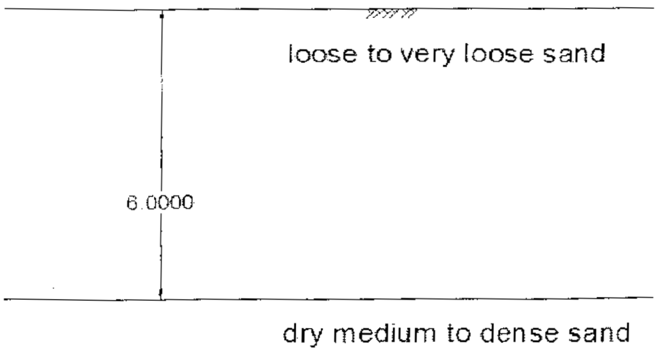


Reasons of choice:

- New Cairo (urban area) : cant use driven piles , so use bored piles.
- Loose to very loose sand: soil can collapse , so use casing.

Site No. 4:

- Given load=1000KN : 2500 KN.
- Position: Cairo-Alex highway.



- Small load value + highway :.

∴ Use bored pile with temporary casing.

- Question (3):

a) From Structural Formula:

1- Driven Pile:(400mm diameter)

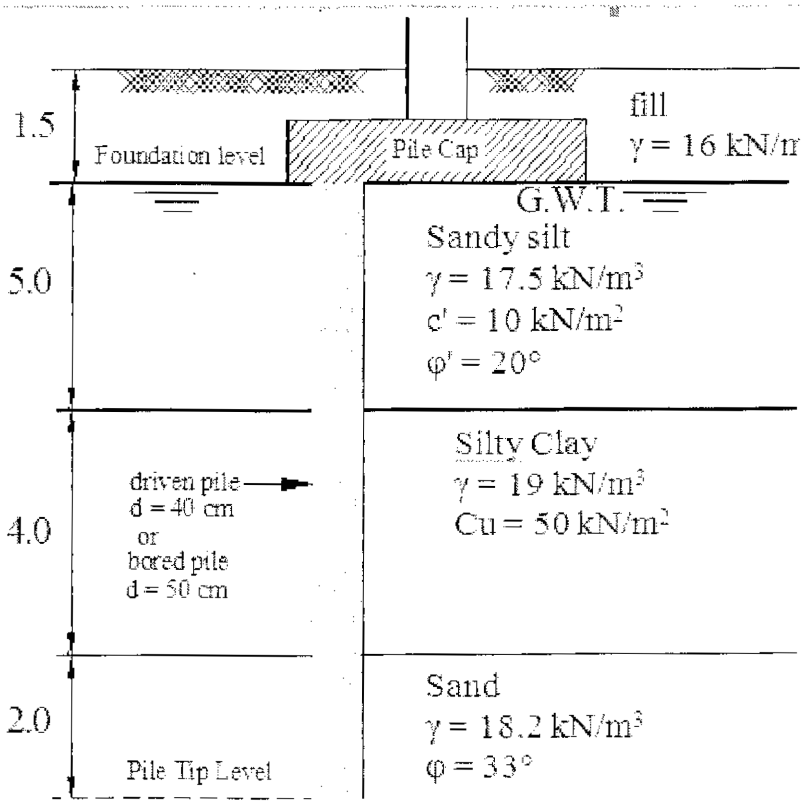
$Q_{all} = A_{pile} * F_{co}$
$= \Pi (400)^2/4 * 4.5$
$= 565486.7$ N $= 565.4867$ KN

2- Bored Pile:(550mm diameter)

$Q_{all} = A_{pile} * F_{co}$
$= \Pi (550)^2/4 * 4.5$
$= 1069120$ N $= 1069.12$ KN

b) From Statical Formula:

1- Driven Pile:(400mm diameter)



a) Compression Capacity:

$Q_{ult} = Q_b + Q_{s1} + Q_{s2} + Q_{s3}$

- Calculation of (Q_b):
Soil (3): is ϕ–soil

- $Q_b = q_b * A_{base}$
- $A_{base} = \Pi (0.4)^2/4 = 0.125$ m2
- $q_b = q * N_q$
- q= 16*1.5+7.5*5+9*4+8.2*2
  = 113.9 KN/m2
- Nq : ϕ = (33+40)/2=36.5 (Driven Pile)

From Table (4-5) :
at ϕ = 35 use N_q=75
at ϕ = 40 use N_q=150

$\therefore N_q = 97.5$

$\therefore Q_b = 113.9*97.5*0.125 = 1388.15$ KN

- Calculation of (Q_{s1}):

Q_{s1}= (Ca + K_{HC}*P_o*tanδ) * $A_{side\ 1}$ (C-ϕ soil)

- A_{side1} = Π (0.4)5 = 6.28 m2
- C_{soil} = 10 KN/m2 -using table (4-4) - ∴Ca= 10KN/m2
- K_{HC} = 1 (Driven Pile)
- P_o=16*1.5+7.5*2.5 = 42.75 KN/m2
- δ = 3/4 *20 = 15
- F_s = (10+ 1*42.75*tan 15) = 21.45 KN/m2
- Q_{s1}=21.45*6.28 = 134.7 KN

- Calculation of (Q_{s2}):

Q_{s2}= Ca * $A_{side\ 2}$ (C- soil)

- A_{side2} = Π (0.4)4 = 5.03 m
- C_{soil} = 50 KN/m2 - using table (4-4) - ∴Ca= 37.5KN/m2
- Q_{s2}= 37.5*5.03 = 188.625 KN

- Calculation of (Q_{s3}):

Q_{s3}= (K_{HC}*P_o*tanδ) * $A_{side\ 3}$ (ϕ soil)

- A_{side3} = Π (0.4)2 = 2.52 m
- K_{HC} = 1 (Driven Pile)
- P_o=16*1.5+7.5*2.5 + 9*4 + 8.2*1= 105.7 KN/m2
- δ = 3/4 *33 = 24.75
- F_s = 1*105.7 *tan 24.75 = 48.72 KN/m2
- Q_{s3} = 48.72*2.52 = 122.78 KN

- Calculation of (Q_{ult}):

- $Q_{ult} = Q_b+Q_{s1}+Q_{s2}+Q_{s3}$
  $=1388.15 + 134.7 + 188.625 + 122.78$
  $=1834.255$ KN

- Calculation of (Q_{all}):

- $Q_{all} = Q_{ult} / FOS = 1834.255/3 = 611.418$ KN $>Q_{all.}$ (str. formula)= 565.48 KN

$\therefore$take $Q_{all} = 565.48$ KN

b) Tension Capacity:

Assume $K_{HC} = K_{HT} = 1$

$\therefore$ $T_{ult} = (Qs1 + Qs2 + Qs3) + O.W._{Pile}$

- $O.W._{Pile} = A_{pile} * L_{pile} * \gamma_{R.C}$
  $= \Pi (0.4)^2/4*11*25$
  $= 34.56$ KN

$\therefore T_{ult} = (134.7 + 188.625 + 122.78) + 34.56$
$= 480.665$ KN

Calculation of (T_{all}):

$\therefore T_{all.} = (134.7 + 188.625 + 122.78) / 3 + 34.56$
$= 183.2$ KN

2- Bored Pile:(550mm diameter)

a) Compression Capacity:

$Q_{ult}=Q_b+Q_{s1}+Q_{s2}+Q_{s3}$

- Calculation of (Q_b):

Soil (3): is ϕ–soil

- $Q_b = q_b * A_{base}$
- $A_{base} = \Pi (0.55)^2/4 = 0.24$ m2
- $q_b = q * N_q$
- q= 16*1.5+7.5*5+9*4+8.2*2 = 113.9 KN/m2
- N_q : $\phi' = (33\text{-}3) = 30$ (Bored Pile)

From Table (4-5) : at $\phi' = 30$ use Nq=30 (Bored)

$\therefore Q_b = 113.9*30*0.24 = 820.1$ KN

- Calculation of (Q_{s1}):

$Q_{s1}= (Ca + K_{HC}*P_o*\tan\delta) * A_{side\ 1}$ (C-ϕ soil)

- $A_{side1} = \Pi (0.55)5 = 8.64$ m2
- Ca= 0.35* C_{soil} = 0.35*10=3.5 KN/m2(Bored)
- $K_{HC} = 0.7$(Bored)
- Q_{s1}= (3.5+ 0.7*42.75*tan 15)*8.64 = 99.52 KN

- Calculation of (Q_{s2}):

$Q_{s2}= Ca * A_{side\ 2}$ (C- soil)

- $A_{side2} = \Pi (0.55)4 = 6.91$m
- Ca= 0.35*50= 17.5KN/m2
- Q_{s2}= 17.5*6.91 = 120.95 KN

-Calculation of (Q_{s3}):

Q_{s3}= (K_{HC}*P_o*tanδ) * $A_{side\ 3}$ (ϕ soil)

- A_{side3} = Π (0.55)2 = 3.46 m
- K_{HC} = 0.7 (Bored)
- Q_{s3} =(0.75*105.7*tan24.75) * 3.46 = 118 KN

-Calculation of (Q_{ult}):

Q_{ult} = Q_b+Qs1+Qs2+Qs3
=820.2 + 99.52 + 120.95 + 118
= 1158.6 KN

-Calculation of (Q_{all}):

Q_{all} = Q_{ult} / FOS = 1158.6 /3 = 386.2 KN <Q_{all}. (str. formula)= 1069 KN

∴take Q_{all} = 386.2 KN

b) Tension Capacity:

- Assume K_{HC} = K_{HT} = 0.7

∴ T_{ult} = (Q_{s1} + Q_{s2}+ Q_{s3}) + O.W.$_{Pile}$

- O.W.$_{Pile}$ = A_{pile} *L_{pile} * $\gamma_{R.C}$
= Π $(0.55)^2$/4*11*25
= 65.34 KN

∴T_{ult} = (99.52 + 120.95 + 118) + 65.34
= 403.81 KN

-Calculation of (T_{all}):

∴T_{all}. = (99.52 + 120.95 + 118) / 3 + 65.34
= 178.165 KN

-Question (4):

Given:

- Precast pile (40*40 cm), Length = 18.00 m
- Single Reaction Hammer , W=30 KN
- Stroke Height (H) = 1.40 m
- $\eta = 0.6$
- C_c= 6mm , C_p = 8mm , C_q = 2mm

Required:

- $Q_{all.}$ using Hiley's Formula, F.O.S= 4

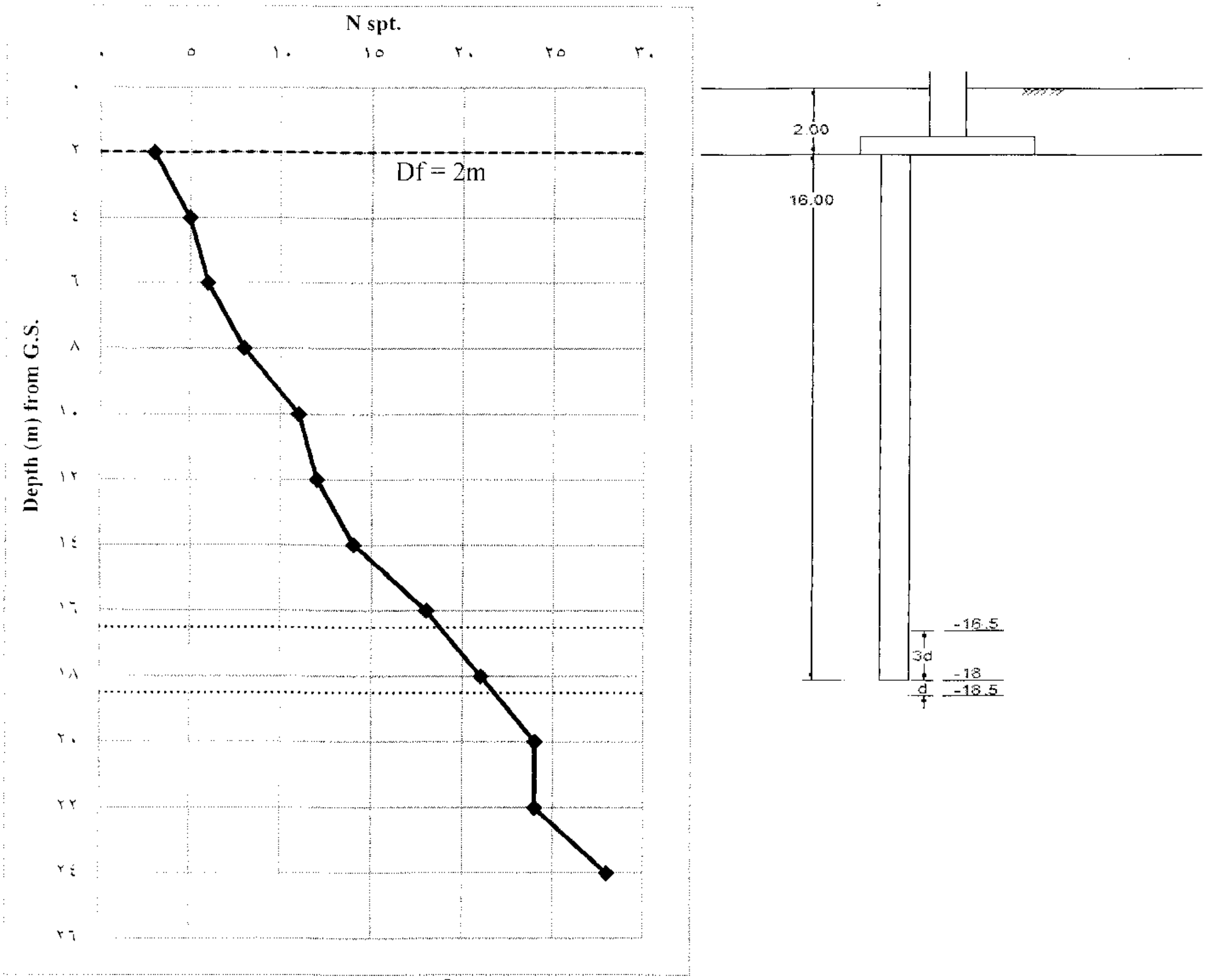
Solution:

- $Q_{ult.} = R_{ult.} = \frac{W*h*\eta}{S+C/2}$ " Hiley's Formula"
- h = 0.9 (Single - action Hammer)
- h = K*H =0.9 * 1.4 =1.26 m
- $C = C_c + C_p + C_q$ =6+8+2 = 16 mm

By sub in Hiley's Formula:

- $R_{ult.} = \frac{30*1.26*0.6}{0.002+0.016/2}$ = 2268 KN
- $Q_{all.}$ = 2268/4 =567 KN

-Question (5):



- $Q_{all.}$ (bored pile) = 0.5 (90Nb * $\Pi d^2/4$ +N' ΠdL)

- N_b = 21 ($N_{average}$ between depth -16.5 : -18.5)
- (the only available value of N_b between depth -16.5 : -18.5 is 21)

- $N' = \frac{3+5+6+8+11+12+14+18+21}{9} = 10.88$

where : N' is N average between depths -2: -18

- $Q_{all.}$ (bored pile) $= 0.5\,(90*21*\Pi*0.5^2/4 + 10.88*\Pi*0.5*16)$
  = 322.3 KN

- **<u>Tension Capacity:</u>**

  - $T_{all.}$ (bored) $= 0.5*N'*\Pi dL + O.W._{Pile}$
  - $O.W._{Pile}$ $= 25*\Pi*0.5^2*16/4 = 78.54$ KN
  - $T_{all.}$ (bored) $= 0.5*10.88*\Pi*0.5*1.6 + 78.54$
    $= 215.27$ KN

- **<u>Compression Capacity (Structural Formula):</u>**

- Q= $= A_{pile} * F_{co}$
  $= \Pi*500^2/4*4$
  $=785398.2$ N $= 785.398$ KN

Note: Structural Formula doesn't take into consideration Soil properties or method of installation.

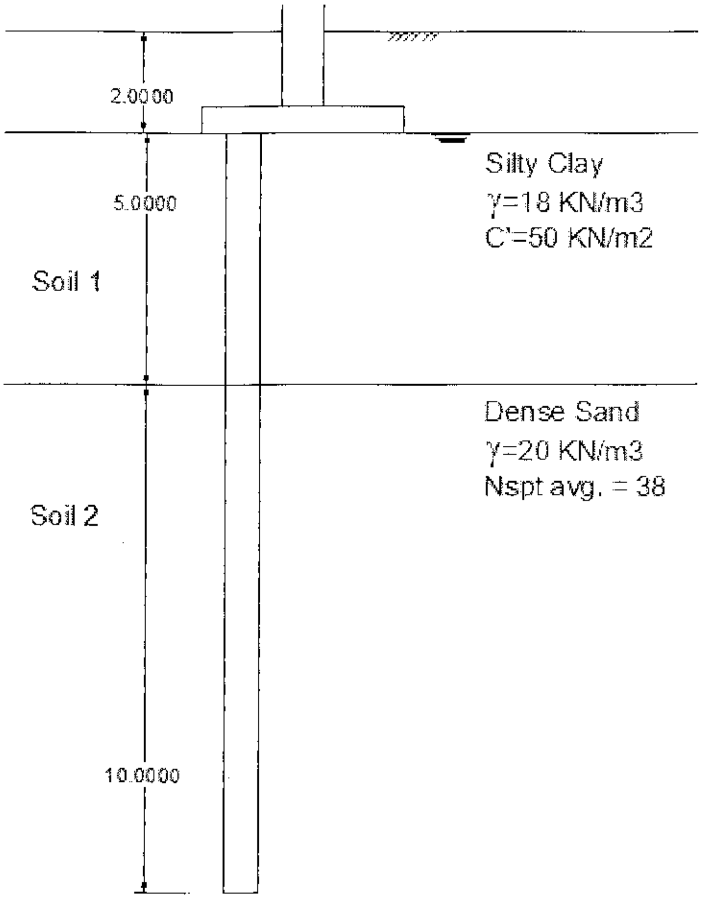
-Question (6):

Given:

- d= 1.20 m
- L_{pile} = 15.00 m

Required:

a) $Q_{ult.}$
b) $Q_{all.}$ at $S_{all.}$ = 25 mm



Solution:

Pile diameter=1.20 m>0.6 m
(large diameter bored pile)
Use ECP load-sett. method

1)OBH Curve: (Q_b - S) Curve:

- Pile bearing layer is Sand:

∴S_b=15 cm (use table (4-8))

$*Q_b = q_b*A_b= q_b* \Pi(1.2)^2/4=1.13q_b$

S (cm)	q_b (KPa)	Qb (KN)
1	500	565
2	800	904
3	1100	1243
15	3400	3842

∴Q max = 3842 KN at Sb = 15 cm

2) OAG Curve: (Q_s - S) Curve:

- to draw OAG curve we need Point (A):

At Point (A): - S_A =1 cm or
=1% d =1.2 cm
$\therefore S_A$=1 cm

- $Q_s\ max = Q_{s1} + Q_{s2} = \Pi d\ (F_{s1}*L1+F_{s2}*L_2)$

where: L_1= 5 m , L2 = 10-d=10-1.2=8.8m

Q_{s1}: (silty clay layer):

- $Q_{s1} = F_{s1}\ \Pi d L_1$
- C_u=50KPa - using table (4-11) $\therefore$ F_s = Ca= 30KPa (by interpolation)

$\therefore Q_{s1}$ = 30*Π*1.2*5 = 565.49 KN

Q_{s2}: (Sand layer):

*Draw F_{s2} distribution using Table (4-10)

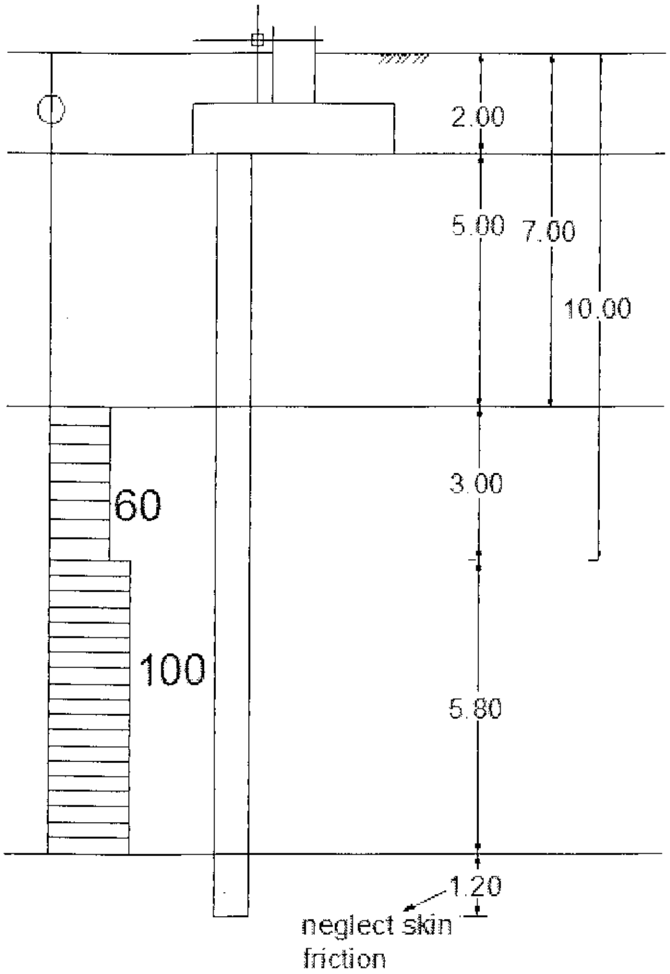
* N_{spt} = 38 > 30

Table (4-10):

N_{spt}	Depth from G.L	F_s (KPa)
>30	0:2 m	Zero
	2:10 m	60
	>10 m	100

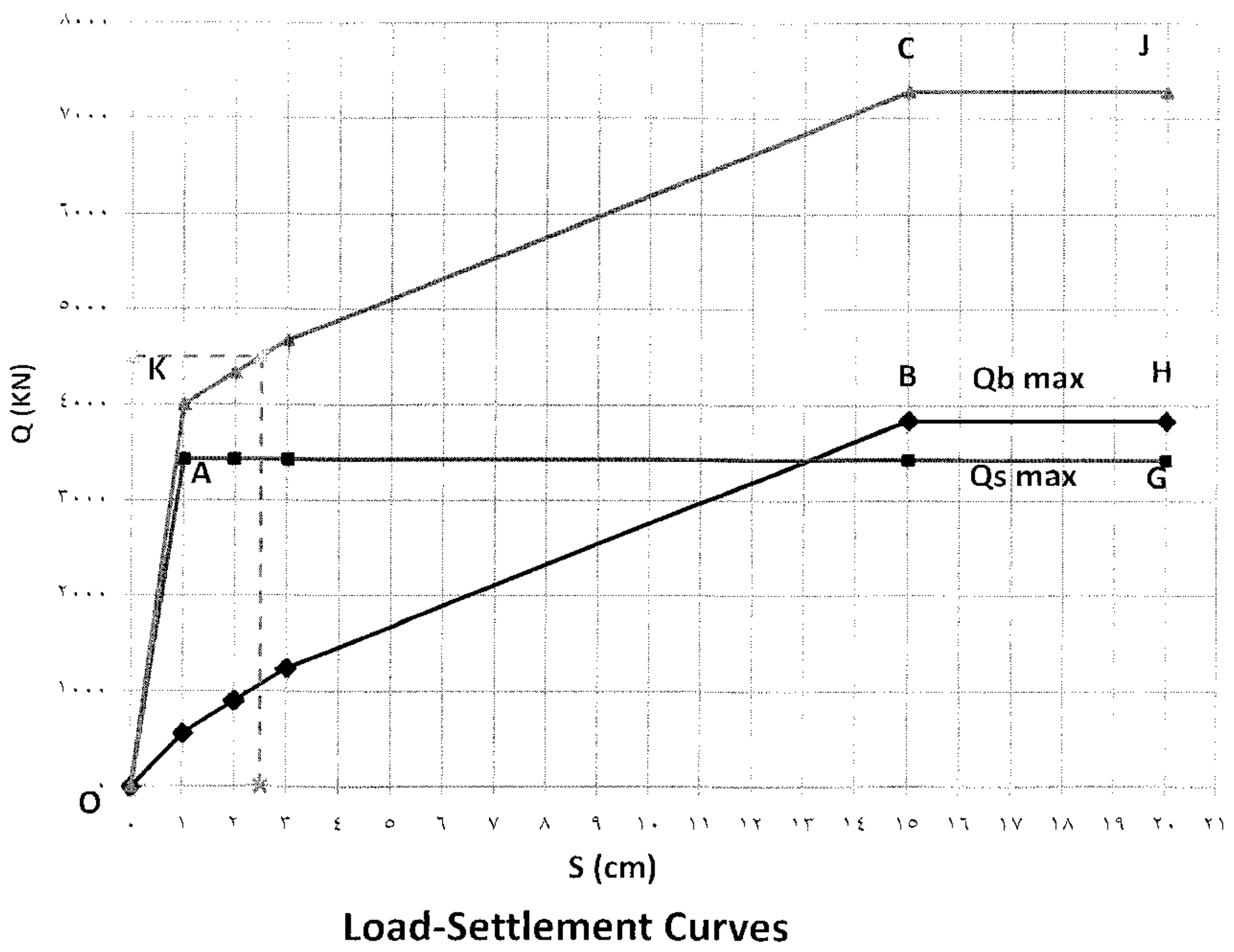
$\therefore Q_{s2}$ = Π*1.2(60*3+100*5.8) = 2865.13 KN

$\therefore Q_{s\ max}$ = Q_{s1} + Q_{s2} = 565.49 + 2865.13
= 3430.62KN



a) $Q_{ult.} = Q_{b\,max} + Q_{smax}$
$= 3842+3430.62$
$= 7272.62$ KN

b) $Q_{all.}$: (Plotting Curves):

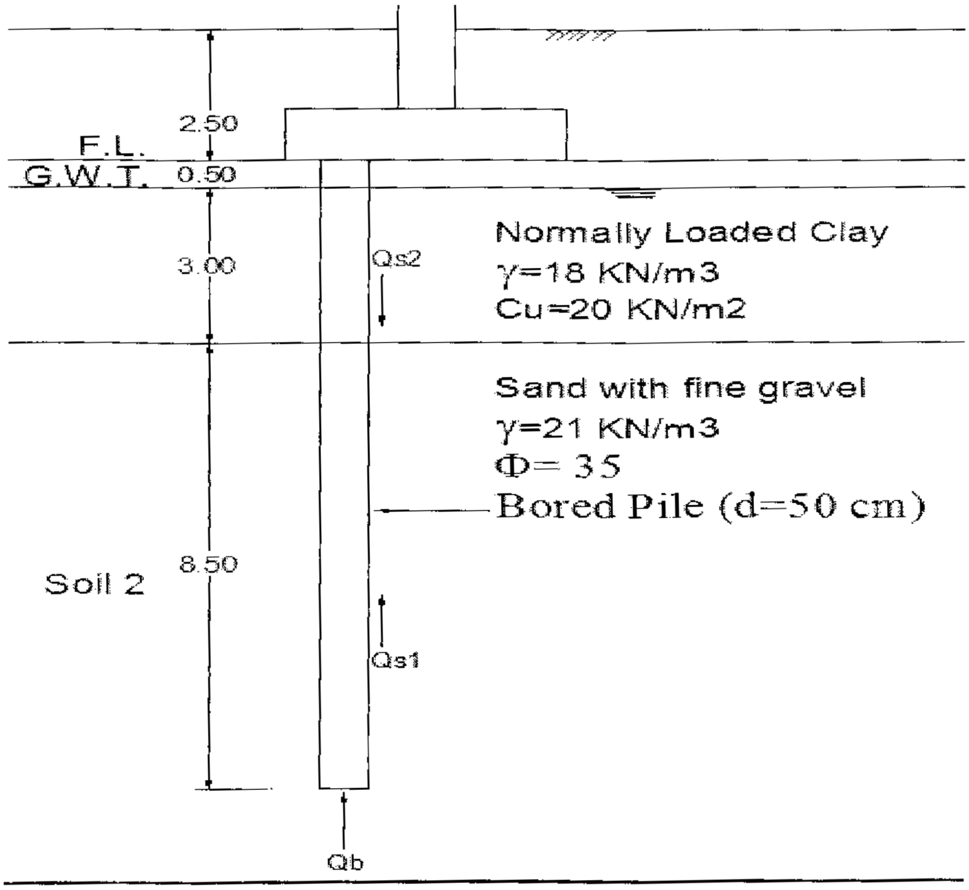


"Drawn to scale"

At $S_{all.} = 2.5$ cm - using OKCJ Curve - ∴ $Q_{all.} = 4500$ KN

-Question (7):

a) The allowable Pile Comp. Load:



1) Q_b: (Φ - Soil):

- $Q_b = q*N_q*A_{base}$
- q = 18*3+8*3+11*8.5=171.5 KPa
- Bored Pile , Φ=35:
  Φ'=35-3=32 - using Table (4-5) - ∴ Nq = 48

- ∴ $Q_b = 171.5*48*\Pi*(0.5)^2/4 = 1616.35$ KN

2) Q_{s1}:

$Q_{s1} = F_{s1} * A_{side\ 1}$

- $As_{ide1} = \Pi\ (0.5)8.5 = 13.35$ m2
- $F_{s1} = K_{HC} * P_o * \tan\delta$

= 0.7* (171.5- 11*4.25)* tan(3/4 *35)
=43.064

- Q_{s1} = 43.064 * 13.35 = 574.97 KN

3) Q_{s2}:

- Normally loaded Clay Layer , C_u= 20 KPa< 25 KPa

∴Negative Skin Friction Occurs.

Q_{s2}= F_{s2} * $A_{side\ 2}$

- A_{side1} = Π (0.5)3.5 = 5.498 m2
- F_{s2}= Ca = 0.35 * 20 = 7 KPa (Bored Pile)
- Q_{s2} = 7 * 5.498 = 38.485 KN

∴ $Q_{all.}$ = (Q_b + Q_{s1}) / FOS - Q_{s2}

= (1616.35 + 574.97) / 3 - 38.484 = 691.955 KN

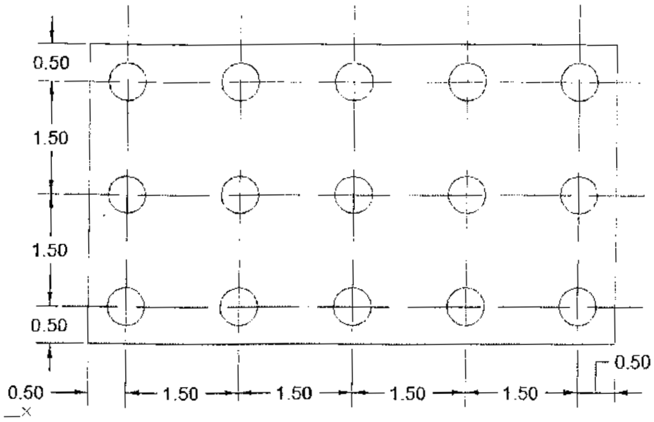
b) Required No. of Piles :

Column Load = 9000 KN

$$n = \frac{1.15*Load}{Q\ all.} = \frac{1.15*9000}{691.955} = 14.96 = 15 \text{ Piles}$$

c) Piles Arrangement :

Assume :
- S=S_{min} = 3d = 1.5 m
- e = d = 0.5 m



Piles Arrangement

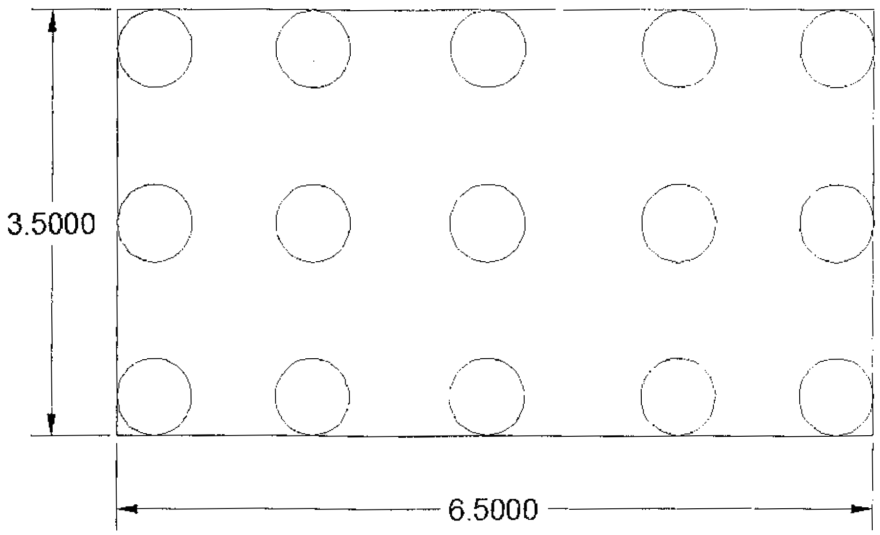
d) Piles Group Settlement :

$S = S_o\sqrt{B/d}$

where: B : the smallest dimension of the Pier .
d : Pile iameter.

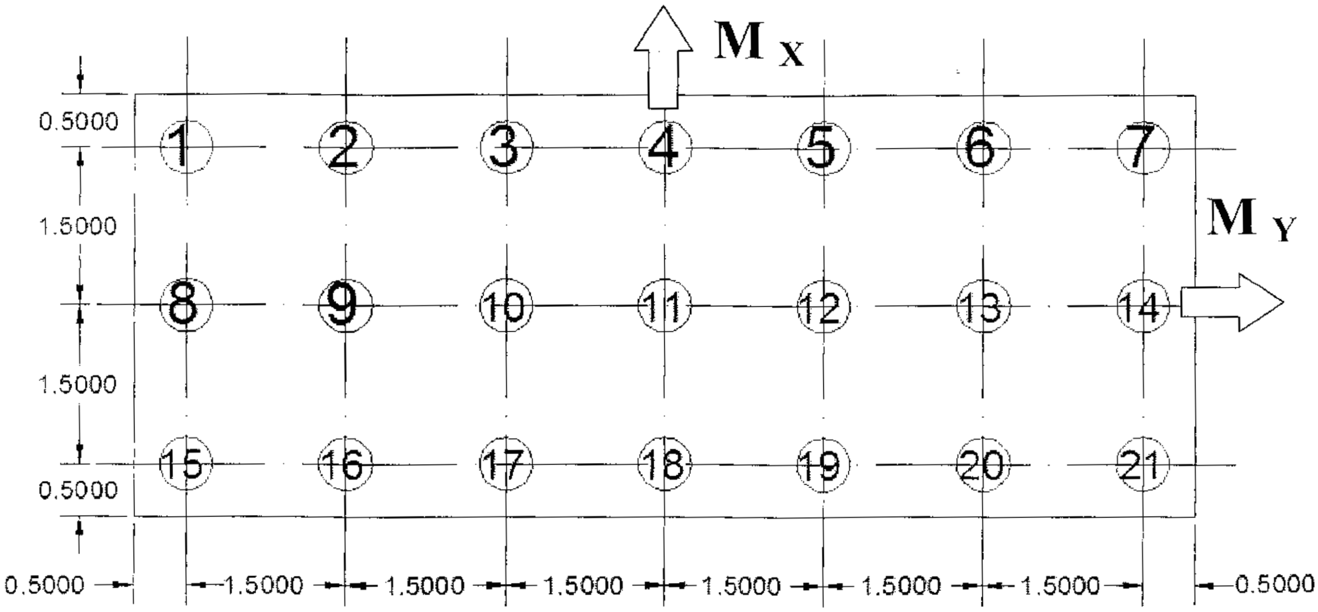
$So = 1\% \, d = 1/100 * 0.5$
$= 0.005$ m

$\therefore \quad S = 0.005\sqrt{3.5/0.5}$
$= 0.0132$ m $= 1.32$ cm



e) Required No. of Piles :

- $N = 9000$ KN , $M_x = 2000$ KN.m , $M_y = 1000$ KN.m
- $e_x = M_y/N = 1000/9000 = 0.11$
- $e_y = M_x/N = 2000/9000 = 0.22$
- n $= 1.15\, N * (1+ e_x) *(1+ e_y)/ Q_{all.}$
  $= 1.15 * 9000* (1+0.11) *(1+0.22) /691.955$
  $= 20.25 = 21$ Piles



- Check No. of Piles :

- $\Sigma X_i^2 = 6 * (4.5)^2 + 6 * (3)^2 + 6 * (1.5)^2 = 189\ m^2$
- $\Sigma y_i^2 = 2 * 7 * (1.5)^2 = 31.5\ m^2$
- $Q_{max\ (at\ Pile\ 7)} = \frac{1.15*9000}{21} + 1000* \frac{4.5}{189} + 2000* \frac{1.5}{31.5}$

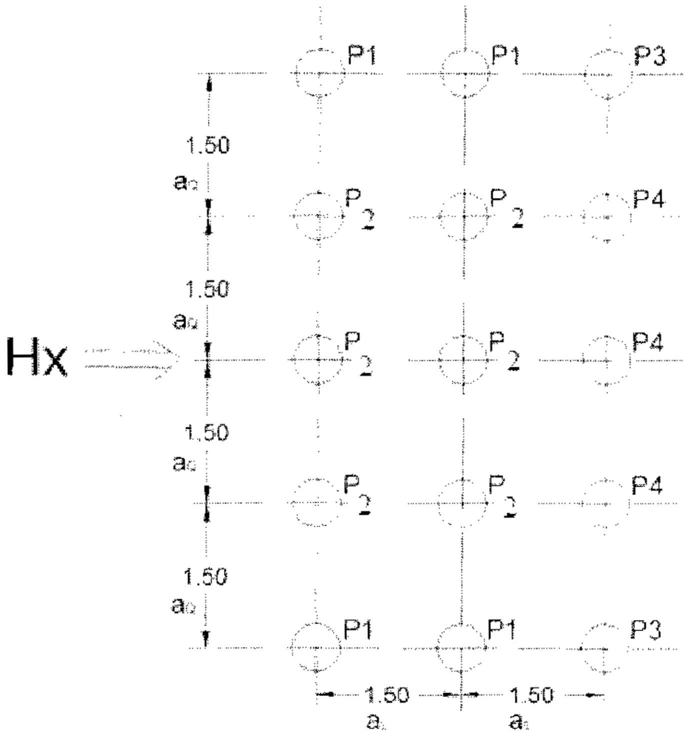
$= 611.9$ KN $< Q_{all.} = 691.955$ KN

- $Q_{min\ (at\ Pile\ 15)} = \frac{1.15*9000}{21} - 1000* \frac{4.5}{189} - 2000* \frac{1.5}{31.5}$

$= 373.81$ KN $>$ zero

f):

$Q_v = 9000$ KN, $H_x = 1500$ KN



- Calculation of Group Action :

Pile Arrangment

Pile	α_L	α_Q	$\alpha_L * \alpha_Q$
1	0.65	$\alpha_{QA}=1$	0.65
2	0.65	$\alpha_{Qz}=1$	0.65
3	1	$\alpha_{QA}=1$	1
4	1	$\alpha_{Qz}=1$	1

$a_L/D_s = 1.5/0.5=3$
$a_Q/D_s = 1.5/0.5=3$

Σ Piles Stiffness Factors = 4*0.65 + 6*0.65 + 2*1 + 3*1= 11.5

$\therefore$Group Action = (1*15)/11.5 = 1.304

-Calculate Relative Pile/Soil Stiffness:

As the pile penetrates Normally loaded Clay and Sand.

$\therefore K_h$ is variable with depth.

- For Clay Layer:

q_u=40 KPa (use n-Table ,interpolation) ∴n =1200

- For Sand Layer:

- Φ = 35 (use Table 3-8 , interpolation) ∴ Dr= 0.575= 57.5 %
- Dr= 57.5 % (use n-Table, interpolation) ∴ n = 10300
- ($n_{avg.}$)= (1200*3.5+10300*8.5) /12 = 7645 .833 KN/m'

- Assume $E_{R.C} = 21*10^6$ KPa

- $t = \sqrt[5]{EI/n} = \sqrt[5]{21 * 10^6 * \Pi * 0.5^4/64 * 7645.833}$ =1.53

∴ L/t = 12/1.53 = 7.83 > 4 (Long Flexible Pile)

-**Calculate $\Delta_{max\ single}$, $M_{max\ single}$: (Single Pile)**

- $H_{avg.} = \frac{Hz\ Force}{no.of\ Piles} = \frac{1500}{15} = 100$ KN
- $\Delta_{max\ single} = \frac{0.88\ H\ t^3}{E\ I} = \frac{0.88*100*(1.53)^3*64}{21*10^6*\Pi*0.5^4} * 1000 = 4.892$ mm
- $M_{max\ single} = 0.88\ H\ t = 0.88 * 100*1.53 = 134.64$ KN.m

- Pile Group :

$\Delta_{max\ group.} = \Delta_{max\ single}$* Group Action
= 4.892 * 1.304
= 6.398 mm

- Hz. Force among individual Piles:

- $Hi = \frac{\alpha Q*\alpha L}{\Sigma\,\alpha Q*\alpha L} * H_{group}$
- $H_1 = \frac{0.65}{11.5} * 1500 = 84.78$ KN
- $H_2 = \frac{0.65}{11.5} * 1500 = 84.78$ KN

- $H_3 = \frac{1}{11.5} * 1500 = 130.434$ KN
- $H_4 = \frac{1}{11.5} * 1500 = 130.434$ KN

- Max Moment among individual Piles:

$M_i = 0.85\ H_i * t = 0.85 * 1.53 * H_i = 1.3005\ H_i$

- $M_1 = 110.26$ KN.m
- $M_2 = 110.26$ KN.m
- $M_3 = 169.63$ KN.m
- $M_4 = 169.63$ KN.m

-The normal Force acting on the individual Piles:

- $Q_{pile} = 9000/15 = 600$ KN

- The required Pile Reinforcement:

- Circular Section subjected to M,N
- $M_{max} = 169.63$ KN.m , N = 600 KN
- Using Interaction Diagrams : (circular Sec.)
- $F_y = 360$ MPa , $\varepsilon = 0.8$

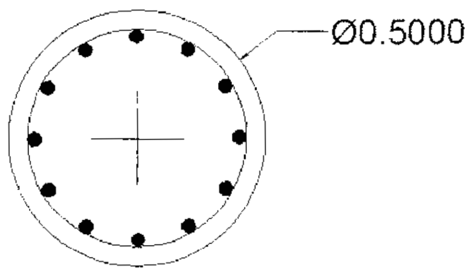
$* M_u / F_{cu} * R^3 = (1.5*169.63*10^6)/(25* 250^3) = 0.651$

$* P_u / F_{cu} * R^2 = (1.5*600*10^3)/(25* 250^2) = 0.576$

$\therefore \rho = 8.4$

$\therefore \mu = \rho * Fcu * 10^{-4} = 8.4 * 25*10^{-4} = 0.021$

$\therefore As = \mu * \Pi * R^2 = 0.021*\Pi*250^2 = 4123.34\ mm^2$
$= 12\ \Phi\ 22$

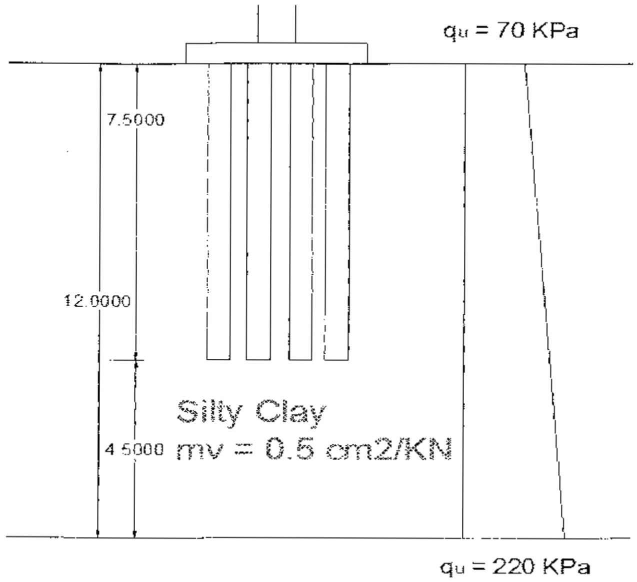


Pile Rft
12Φ22

-Question (8):

Given :

- All Group Settlement = 25 mm
- 25 Square Piles (25x25cm) , spaced 1.0 m center to center.



Required :

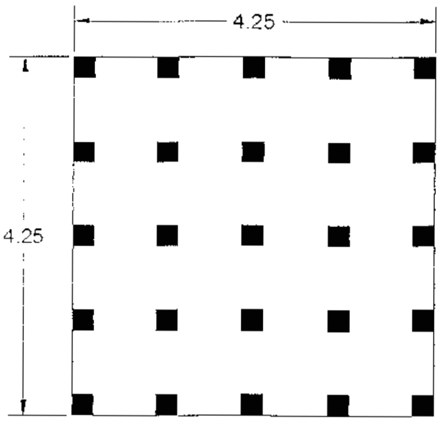
1) Allowable Compression Load on Pile group.

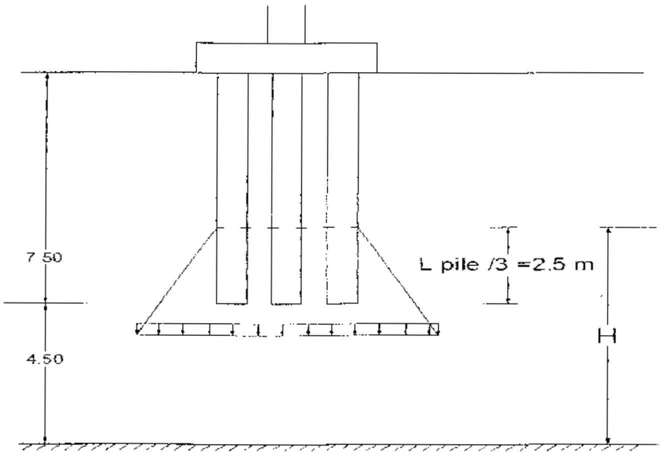
2) The Single Pile Capacity under tension Forces.

-Solution :

1) Allowable Comp. Load on Pile group :

a- Group capacity from group Settlement:





L=B=4*1+d = 4.25 m

- $S_{gall.} = mv * \Delta\sigma * H$

where: - H= 4.5+7.5/3 = 7.00 m

$$- \Delta\sigma = \frac{Qg\ all.}{\left(L+\frac{H}{2}\right)(B+H/2)} = \frac{Qg\ all.}{\left(4.25+\frac{7}{2}\right)(4.25+\frac{7}{2})}$$

$$\therefore\ 0.025 = 0.5*10^{-4} * \frac{Qg\ all.}{\left(4.25+\frac{7}{2}\right)(4.25+\frac{7}{2})} *7$$

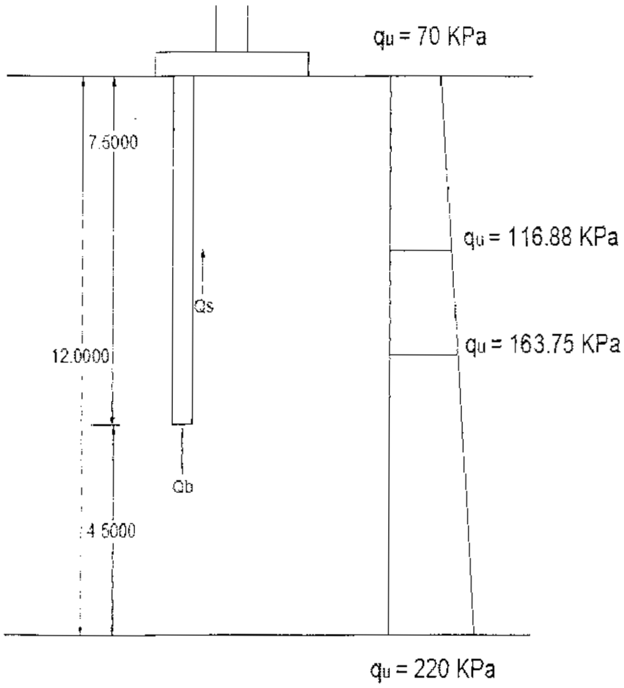
$\therefore\ Q_{gall.} = 4290.18$ KN

b- Group capacity from Single Pile Capacity:

- Q_b:

$Cu_{base} = (q_{un\ base} / 2) = 163.75/2 = 81.875$ KPa

$Q_b = 81.875 * 9*0.25^2 = 46.05$ KN



-Q_s :

$Q_s = F_s * A_{side}$

- $C_{a@Lpile/2} = q_{un} /2 = 116.88/2 = 58.44$ KPa
- C= 58.44 KPa , (Driven Pile)

$\therefore$ From Table (4- 4) : $C_a = 39.2$ KPa

$\therefore\ Q_s = 39.2*4*0.25*7.5 = 294$ KN

-$Q_{all.}$:

$Q_{all.\ single\ pile} = (Q_b+Q_s)/FOS = (46.05+294)/2.5 =$ 136.02 KN

-$Q_{all.\ group}$:

$Q_{all.\ g} = Ge * n * Q_{all.\ s}$

We can get Ge for Clayey Soil from Figure (4-22)

S/d = 1/0.25 = 4 , L/d = 7.5/0.25 = 30

Group (5*5):

- By interaction from curve ∴ Ge = 0.83

∴ Qall.g = 0.83 * 25*136.02 =2822.415 KN

∴ Qall g = Minimun of (4290.18 , 2822.415) = 2822.415 KN

2)Single Pile Capacity under Tension Force:

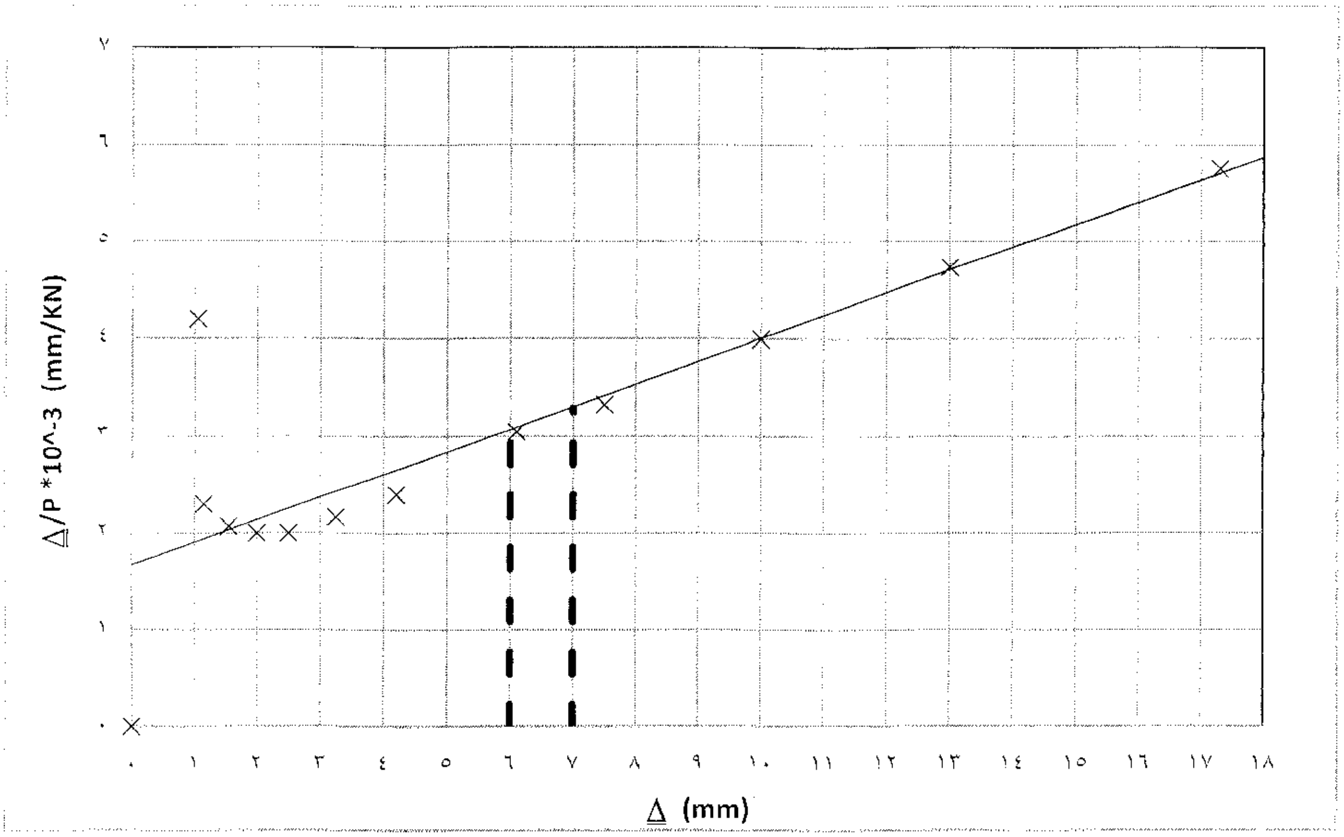
$T_{ult} = Q_s + o.w.$
$= 294 + (0.25^2 * 7.5 * 25) = \quad 305.72$ KN

-Question (9):

According to the given relation between Load (P) and Settlement (Δ) we can construct the following table (Measuring from the given given Figure) in the loading direction only :

P (KN)	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
Δ (mm)	0	1.05	1.15	1.55	2.00	2.50	3.25	4.20	6.1	7.5	10	13	17.3
Δ/P (mm/Kn)	0	4.2	2.3	2.07	2	2	2.167	2.4	3.05	3.33	4	4.73	5.76

Then we can Conclude the following curve:



a) From the best fit Line :

$b = 0.25*10^{-3}$

$\therefore Q_{ult.} = 1/(1.2b) = 1/(1.2*0.25*10^{-3}) = 3333.33$ KN

b) $Q_{all.}$ = Q ult./ FOS = 3333.33 / 2 = 1666.67 KN

c) Pile stiffness at working Load means Pile stiffness at Q all.

From given curve:

At $Q_{all.}$ = 1666.67 KN $\therefore \Delta = 3.90$ mm

$$\therefore \text{Single Pile Stiffness} = \frac{\text{Q all.}}{\Delta \text{ all.}}$$

$$= \frac{1666.67}{3.9*10^{-3}}$$

$$= 4.21 * 10^5 \text{ KN/m}$$

-Question (10):

Given :

$P_{col.} = 5000KN$, Col. Dim. =40*110 cm

$Q_{all.} = 800$ KN , $\Phi_{pile} = 50$ cm

$F_{cu} = 30$ MPa , $F_y = 360$ MPa

- Solution :

1) Calculation of no. of piles and piles arrangement:

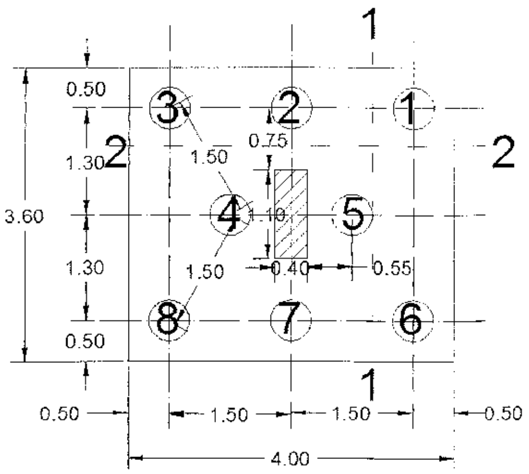
$n_{piles} = \frac{1.15\ Pcol}{Qall.} = \frac{1.15*5000}{800} = 7.18 = 8$ Piles

Use S =S_{min} = 3Φ = 1.50 m

Use e = Φ = 0.50 m

Calculate Ult. Reaction on Pile :

$Q_{ult.\ pile} = \frac{1.5\ Pcol}{n\ piles} = \frac{1.5*5000}{8} = 937.5$ KN



3) Calculation of moment at critical Sections (column edges):

Sec. (1)

M_{u1} = (Qu1+Qu6)*1.3+Qus*0.55
= (2*937.5*1.3)+ 937.5*0.55
= 2953.125 KN.m/B

$d_1 = C1\sqrt{\frac{Mu1*10^6}{Fcu*B}}$
$= 5\sqrt{\frac{2953.12*10^6}{30*3600}}$
= 826.8 mm

Sec. (2)

M_{u2} = (Qu1+Qu2+Qu3)*0.75
= (3*937.5*0.75)
= 2109.4 KN.m/L

$d_2 = C1\sqrt{\frac{Mu2*10^6}{Fcu*L}}$
$= 5\sqrt{\frac{2109.4*10^6}{30*4000}}$
= 662.92 mm

$d_{bigger} = d_1$ = 826.8 mm

- Check (d min):

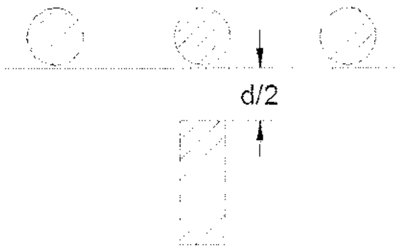
$d_{min} = 2\ \Phi = 2*500 = 1000$ mm

4)Check Shear: (at d/2 from column edge) :

Sec (1) :

- Q_{s1} =2*937.5+0.6*937.5
  = 2437.5 KN
- $q_{s1} = Q_{s1} / (B*d)$
  =2437.5*1000 / (3600*1000)
  = 0.667 N/mm^2
- $q_{scu} = 0.16\sqrt{30/1.5} = 0.715$ MPa > q_{s1} (safe)

Sec(2) :



- $Q_{s2} = Q_{s1} + Q_{s2} + Q_{s3}$
- Q_{s2} = 3*937.5 = 2812.5 KN
- $q_{s2} = Q_{s2} / (L*d)$ = 2812.5 / (4000*1000)
  = 0.703 MPa<qscu = 0.715 MPa (safe)

5) Check Punching :

- Q_{pu} = 1.5*Pcol. - Σ $Q_{ult/piles\ insidecritical\ sec.}$

  = 1.5*5000 - 2*0.4*937.5
  = 6750 KN

- q_{pu} $= \frac{Qpu}{d*perimeter}$

  $= \frac{6750*1000}{1000*2(1400+2100)}$

  = 0.964 MPa

- q_{pcu} $= 0.316\ (0.5+a/b)\sqrt{Fcu/\gamma c}$

  $= 0.316\ (0.5+0.4/1.1)\ \sqrt{30/1.5}$

  = 1.22 MPa>q_{pu} (safe)

6) Safe Thickness of RC Section:

t_{safe} = d + cover
= 1000+100 = 1100 mm

7) RFT :

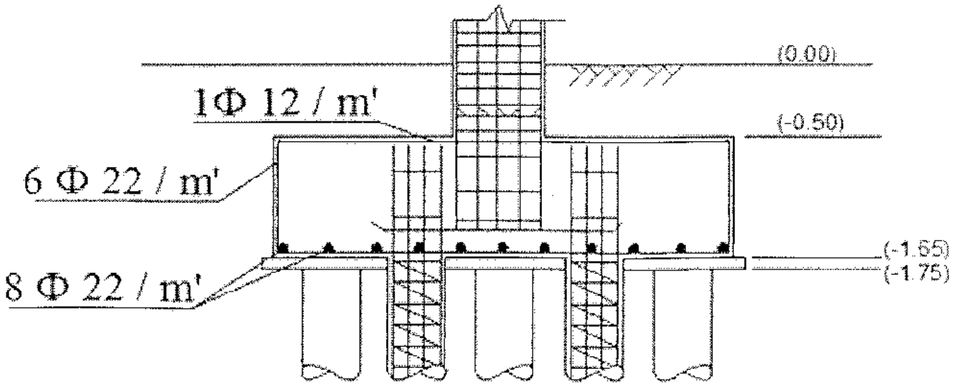
As_{min} = 1.5d = 1.5*1000= 1500 mm^2

$A_{s1} = M_{u1}/F_y*J*d$ *1/B = 2953.12*10^6 / (3600*0.826*1000) *1/3.6 = 2758.65 mm^2/m
= 8 Ø 22/m

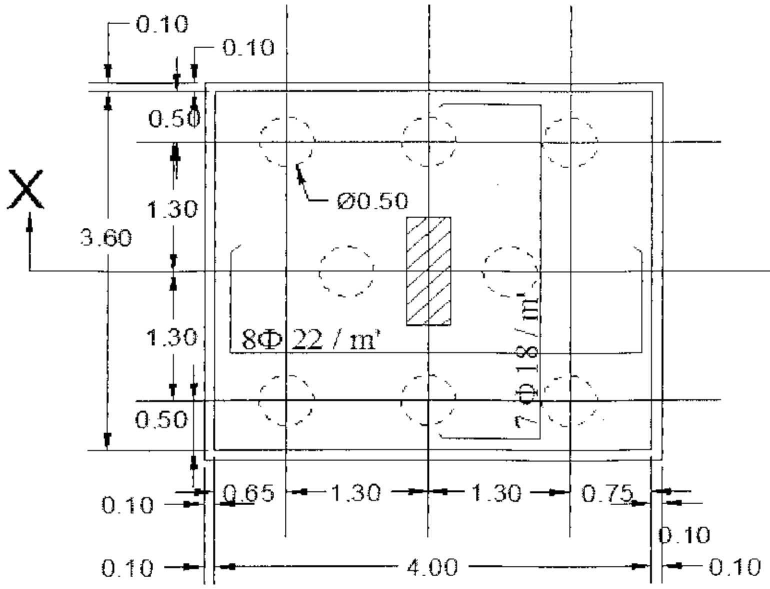
$A_{s2} = M_{u2}/F_y*J*d$ *1/L = 2109.4*10^6 / (3600*0.826*1000) *1/4 = 1773.44 mm^2/m
= 7 Ø 18/m

8) RFT Details :

Scale 1:50



Sec. (x-x)



Plan

-Question (11):

Given :

- Col (40x110) cm.
- N=5000 KN , M_x = 500 KN.m , M_y = 600 KN.m
- d= 50 cm , $Q_{all.}$ =800 KN
- F_{cu} = 30 MPa , F_y = 360 MPa

Required :

Design of pile cap + RFT Details

Solution :

$e_x = M_y/N = 600/5000 = 0.12$ m , $e_x = M_x/N = 500/5000 = 0.10$ m

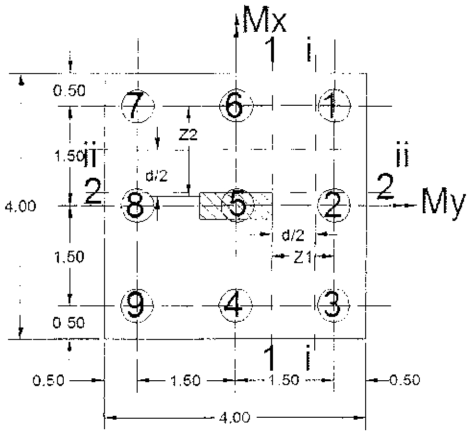
$n = 1.15N / Q_{all.}(1+ e_x) *(1+ e_y)$

$= 1.15*5000 /800 *(1+ 0.12) *(1+ 0.10) = 8.85 = 9$ Piles

-Arrangement of Piles:

Assume S_{min} =3d =1.50 m , e=d= 0.5m

Check Q_{max} , Q_{min}:



$\Sigma(X_i)^2 = 3*1.5^2 + 3*0^2 + 3*(-1.5)^2 = 13.5m^2$

$\Sigma(Y_i)^2 = \Sigma(X_i)^2 = 13.5$

$\therefore Q_{max\ pile1} = \frac{1.15*5000}{9} + \frac{1.5*600}{13.5} + \frac{1.5*500}{13.5} = 761.11$ KN < $Q_{all.}$

$\therefore Q_{min\ pile9} = \frac{1.15*5000}{9} - \frac{1.5*600}{13.5} - \frac{1.5*500}{13.5} = 516.76$ KN > 0

- Ultimate Load/each Pile:

- $Q_{u1} = \frac{1.5*5000}{9} + \frac{1.5*600*1.5}{13.5} + \frac{1.5*500*1.5}{13.5} = 1016$ KN
- $Q_{u2} = \frac{1.5*5000}{9} + \frac{1.5*600*1.5}{13.5} + 0 = 933$ KN
- $Q_{u3} = \frac{1.5*5000}{9} + \frac{1.5*600*1.5}{13.5} - \frac{1.5*500*1.5}{13.5} = 850$ KN

- $Q_{u4} = \frac{1.5*5000}{9} + 0 - \frac{1.5*500*1.5}{13.5} = 750$ KN
- $Q_{u5} = \frac{1.5*5000}{9} + 0 + 0 = 833$ KN
- $Q_{u6} = \frac{1.5*5000}{9} + 0 + \frac{1.5*500*1.5}{13.5} = 916$ KN
- $Q_{u7} = \frac{1.5*5000}{9} - \frac{1.5*600*1.5}{13.5} + \frac{1.5*500*1.5}{13.5} = 816$ KN
- $Q_{u8} = \frac{1.5*5000}{9} - \frac{1.5*600*1.5}{13.5} + 0 = 733$ KN
- $Q_{u9} = \frac{1.5*5000}{9} - \frac{1.5*600*1.5}{13.5} - \frac{1.5*500*1.5}{13.5} = 650$ KN

-Calculation of Moment at Critical section:

Sec. (1)

$M_{u1} = (Qu1+Qu2+Qu3)*z1$

$= (1016+933+850)(1.5-1.1/2)$

$= 2659.05$ KN.m

$d_1 = C1\sqrt{\frac{Mu1*10^6}{Fcu*B}}$

$= 5\sqrt{\frac{2659.05*10^6}{30*4000}}$

$= 744.3$ mm

Sec. (2)

$M_{u2} = (Qu1+Qu6+Qu7)*z2$

$= (1016+916+816)(1.5-0.4/2)$

$= 3572.4$KN.m

$d_2 = C1\sqrt{\frac{Mu2*10^6}{Fcu*L}}$

$= 5\sqrt{\frac{3572.4*10^6}{30*4000}}$

$= 862.7$ mm

$d_{bigger} = d_2 = 862.7$ mm $< d_{min} = 2d = 1000$ mm (take $d = d_{min} = 1000$ mm)

4)Check Shear: (at d/2 from column edge) :

Sec (i) :

- $Q_{su} = (Q_{u1}+Q_{u2}+Q_{u3})$
  $= (1016+933+850)$
  $= 2799$ KN
- $q_{su} = Q_{su} / (B*d)$
  $= 2799*1000 / (4000*1000)$
  $= 0.70$ N/mm^2
- $q_{scu} = 0.16\sqrt{30/1.5} = 0.715$ MPa > qs1 (safe)

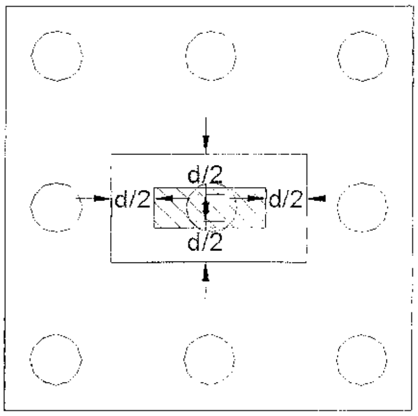
Sec(ii) :

- Q_{su} = $(Q_{u1}+Q_{u6}+Q_{u7})$
  = (1016+916+816) = 2748 KN

- q_{su} = Q_{su} / (L*d) = 2748 / (4000*1000)
  = 0.715MPa<qscu = 0.715 MPa (safe)

5) Check Punching :

- Q_{pu} = 1.5*$P_{col.}$ - Qs
  = 1.5*5000 - 833
  = 6667 KN



$\therefore q_{pu} = \frac{Qpu}{d*perimeter}$

$= \frac{6667*1000}{1000*2(1500+2200)} = 0.9$ MPa

- q_{pcu} = $0.316\ (0.5+a/b)\sqrt{Fcu/\gamma c}$

  $= 0.316\ (0.5+0.4/1.1)\ \sqrt{30/1.5}$

  = 1.22 MPa>q_{pu} (safe)

- Final R.C thickness :

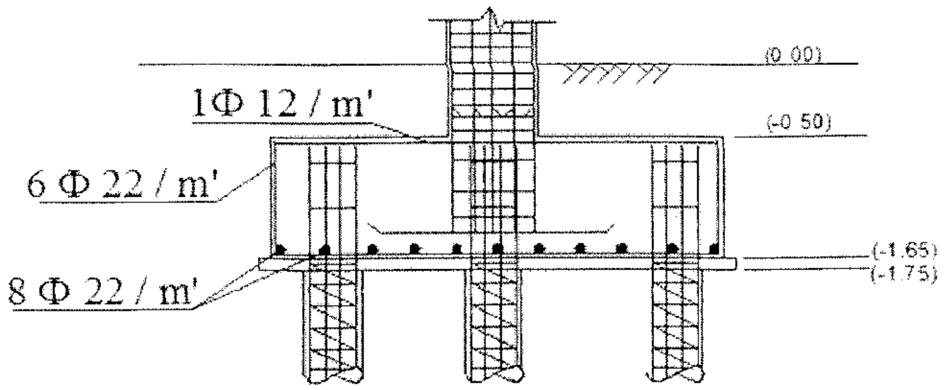
- t = d+150mm = 1150 mm

- RFT.:

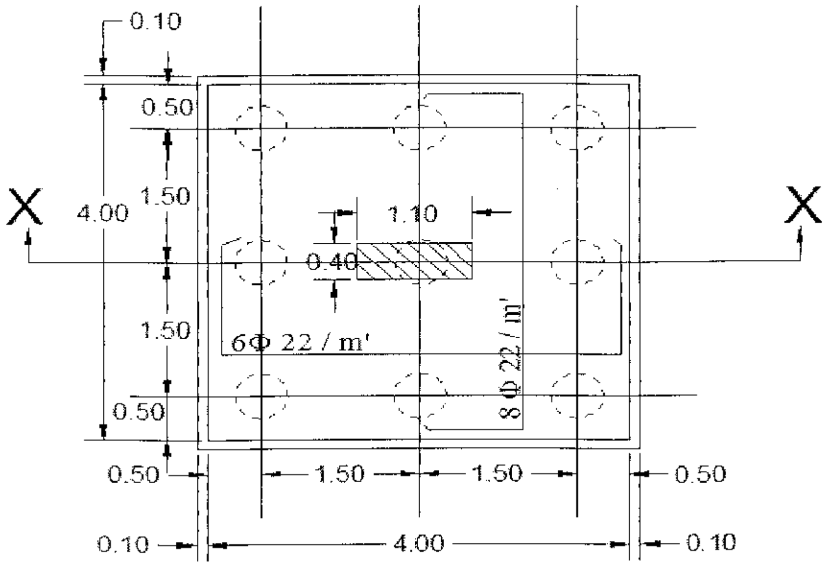
- $A_{smin} = 1.5\ d = 1500 mm^2/m$

- $A_{s1} = \frac{2659.05*10^6}{360*0.826*1000}$ /4.00 = 2235 mm^2/m = 6 Ø 22/m

- $A_{s2} = \frac{3572.4*10^6}{360*0.826*1000}$ /4.00 = 3003.43 mm^2/m = 8Ø 22/m


1Φ 12 / m'
6 Φ 22 / m'
8 Φ 22 / m'
(0.00)
(-0.50)
(-1.65)
(-1.75)

Sec. (x-x)


0.10
0.50
1.50
4.00
1.50
0.50
X
X
1.10
0.40
6Φ 22 / m'
8 Φ 22 / m'
0.50
1.50
1.50
0.50
0.10
4.00
0.10

Plan