Correction for SPT-N values:

Page 13-18
P.C. Varghese

Q. Correct the SPT-N value for
a) Overburden Pressure
b) Submergence in case of very fine silty sand

⇒ a) All field SPT value after 1974 are corrected as proposed by Peck, Hanson and Thornburn which can be represented as follows:

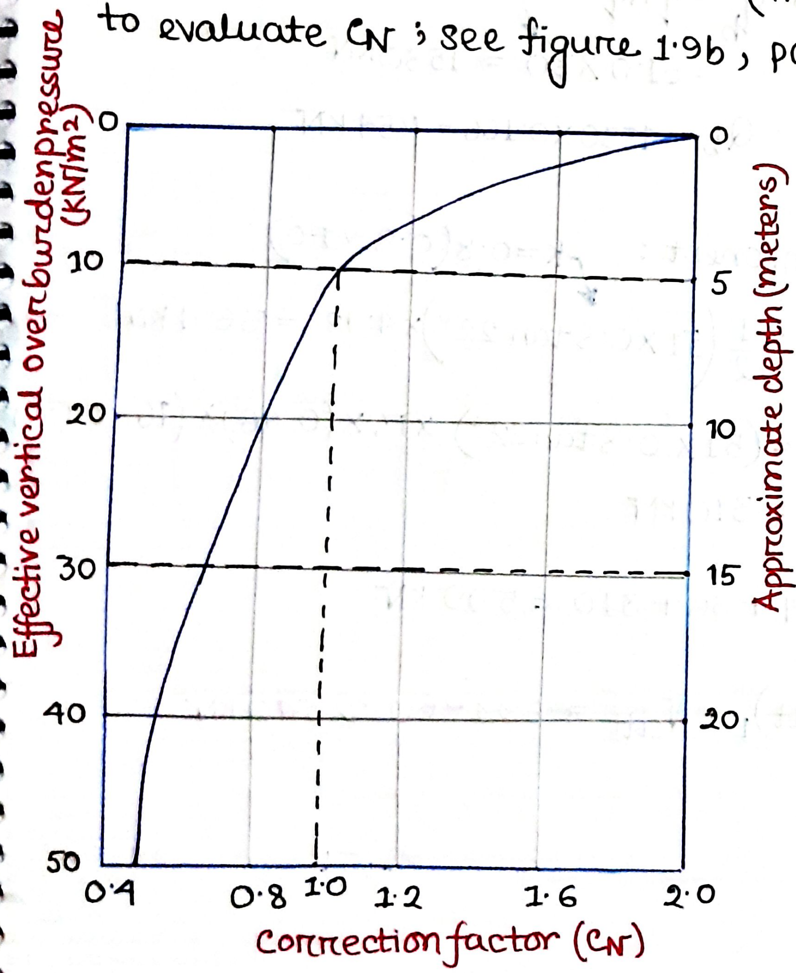
$$C_N = 0.77 \log_{10} (2000/P)$$

$$N_{c\,(corrected)} = C_N * N \quad ; N \rightarrow \text{field SPT}$$

P → Overburden pressure in KPa

For P = 100 KN/m² or 1 kg/cm² (for overburden pressure at 5m depth using $\gamma_{soil} = 20\ KN/m^3$) The correction factor N_c will be equal to $0.77 \log_{10} 20$ which is equal to unity.

Note that no correction is generally applied to position of water level for sands unless it is fine. (That is, use total overburden pressure to evaluate C_N ; see figure 1.9b, page 15 ; Varghese)



⇒ b) Correction for silts and fine sands below water level:

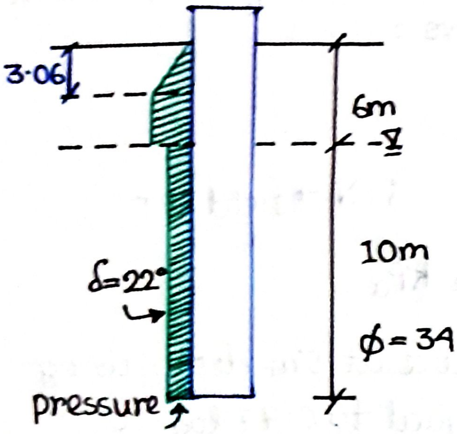
The correction for values of N greater than 15 in fine sands below water level is as follows:

$$N_c = 15 + 0.5\ (N-5)$$

This correction is due to the fact that higher values are liable to be recorded due to pore pressure.

16-1
Page-963
Bowles

A 460 mm diameter pipe pile is driven closed-end 15 m into a cohesionless soil with an estimated ϕ angle of 34°. The soil has a $\gamma_d = 16.5$ KN/m³, $\gamma' = 8.60$ KN/m³. The GWT is 6m below the ground surface. Estimate the ultimate pile capacity Pu using Tarzaghi's method and friction angle δ



$K = 0.8 \sim 1.0$

$q_f = [\sigma_r K_0] \tan\delta \; A_f$

Critical Depth:

$y = \frac{z_c}{d}$, $x = \phi°$

$\frac{y-5}{5-7.2} = \frac{x-28}{28-36}$

$\Rightarrow y = 0.275x - 2.7$
$\phi < 36°$

for $\phi > 36°$

$\frac{y-7.2}{7.2-15} = \frac{x-36}{36-40}$

$\Rightarrow y = 1.95x - 63$

$\gamma_d = 16.5$ KN/m³ (assumed)

$A_p = \frac{\pi}{4}(0.46)^2 = 0.166\ m^2$

Critical depth:

for $\phi = 34°$, $z_c/d = 0.275 \times 34 - 2.7 = 6.65$

$\therefore z_c = 6.65 \times 0.46 = 3.06$

$\sigma_{zc} = \gamma_z =$

$A_{f1} = \pi(0.46)(3.06) = 4.42$

$A_{f2} = \pi(0.46)(6-3.06) = 4.25$

$A_{f3} = \pi(0.46) \times 10 = 14.45$

End Bearing: $q_b = q N_q$ → for $\phi = 34°$, $N_q = 31$

$= 51.0 \times 30 = 1530$ KN

$Q_b = 1530 \times 0.166 = 254$ KN

Frictional Component: $K = 0.8\ (0.8 \sim 1.0)$

Part 1 : $Q_{f1} = \frac{1}{2}(51 \times 0.8 \tan 22°) \times 4.42 = 36.4$ KN

$Q_{f2} = (51 \times 0.8 \tan 22°) \times \pi \times (0.46) \times (16 - 3.06)$

$= 310$ KN

$(Q_{ult})_1 = 254 + 36 + 310 = 599$ KN

$\therefore Q_{ult} = (Q_{ult})_1 - W_{silt} = 599 - 60 \approx 540$ KN

Ex 16-3
Page 9
Bowles

Estimate the ultimate pile capacity of a 300mm round concrete pile that is 30m long with 24m driven into a soft clay soil of average $q_u = 24$ KN. Assume $\gamma' = 8.15$ KN/m3 for the soil. The water surface is 2m above the ground line.

$$A_p = \pi/4 * (0.3)^2 = 0.071\ m^2$$

$$A_f = \pi * (0.3)(24) = 22.62\ m^2$$

Post Bearing: $q_b = c N_c A_p = \frac{q_u}{2} N_c A_p$

$$= \left(\frac{24}{2}\right)(6.2)(0.071) = 5.3\ KN$$

↑ surface friction pile, better not to use D_f/B factor.

Friction pile: $q_f = (\alpha_a c) A_f$

$$= \left(0.9 * \frac{24}{2}\right) * 22.62 = 244.3\ KN$$

$\alpha_a = 0.9$ (Since the soil is soft)

Self weight of the pile $W_p = [0.071 \times 30] = 24\cdot$ KN

$\gamma_{conc} = 24$ KN/m3 $= 51$KN

$$\therefore q_{ult} = q_{ult} - W_p = 250 - 50 = 200\ KN$$

(Ans.)

Tension Piles:

- Used beneath . to resist uplift from hydraulic pressure.
- To support structures over expansive soils.
- Over-turning caused by wind, ice loads, and broken wires may produce larger tension faces for power transmission towers. In this of this piles and piers supporting the tower, must be designed for both comp. & tension faces.

Ex-16-3 Page 963 Bowles

A pile is driven through a soft cohesive deposit overlying a stiff clay. The GWT is 5-m below the ground surface and the stiff clay is at the 8m depth.

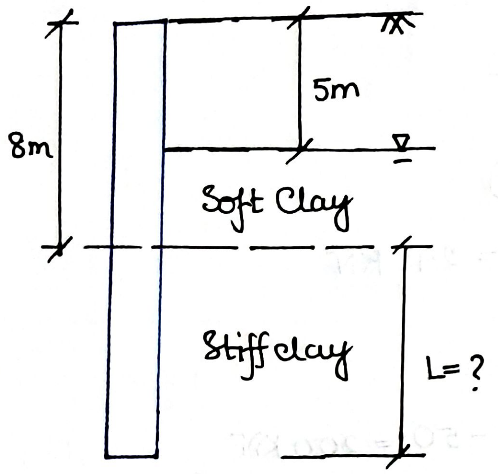
Other data:

	Soft clay	Stiff clay	
γ_{wet}	17.5	19.3	KN/m3
γ'	9.5	10.6	KN/m3
Su	50	165	KN/m3

Estimate the length of a 550 mm diameter pile is carrying an allowable load:

$P_a = 420$ KN using an

$S_F = 4.0$ & Tarzaghi's method.



c = Su

Solution:

$A_p = \frac{\pi}{4}(0.55)^2 = 0.238$ m

$(A_f)_1 = \pi * (0.55) * 8 = 13.8$ m

$(A_f)_2 = \pi * (0.55) * L = 1.73L$

Assume: End point is extended into the stiff clays.

End Bearing: $q_p = [c N_p A_p]$

$= [165][6.2][0.238] = 243$ KN

Skin friction:

part 1 : $[q_{f1}] = [\alpha_a c_1][A_{f1}]$

$= [0.85 \times 50][13.8] = 586.5$ KN

$\alpha_a = 0.85$
(soft to medium clay)

part 2 : $[q_{f2}] = [\alpha_a c_2][A_{f2}]$

$= [0.5 \times 165][1.73 \times L] = 142.7L$

$\alpha_a = 0.5$
(stiffclay)

$q_{ult} = q_p + [q_{f1}] + [q_{f2}] = 243 + 586.5 + 142.7L$

$\therefore q_{allow} = \frac{q_{ult}}{FS} = \frac{830 + 142.7L}{4} = 207.4 + 35.7L$

or, $q_{allow} = 420 = 207.4 + 35.7L \Rightarrow L = 6$m

$\therefore$ total length of pile $= 8 + L = 8 + 6 = 14$m (Ans.)

Ex 16-8

Page 964 Bowles.

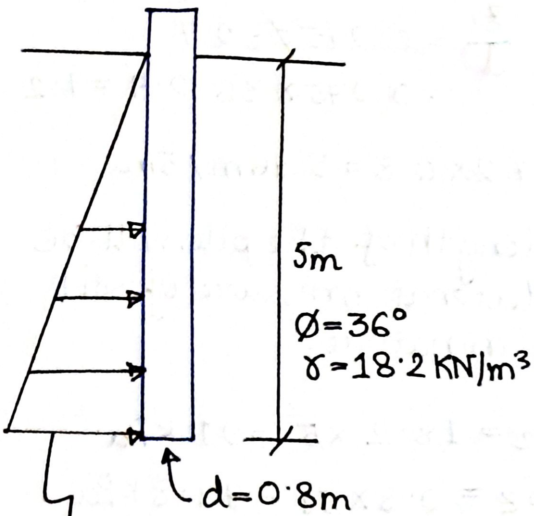
What is the approximate ultimate pullout resistance T_u for a tension pile in a medium dense sand with $\phi = 36°$, $\gamma = 18.2\ KN/m^3$ and using an 800-mm diameter concrete pile with a length of 5m (and no ball)?

$\delta = \frac{2}{3}\phi = 24°$

for $\phi = 36°$; $\frac{z_c}{d} = 0.275\phi - 2.7$
$= 0.275 \times 36 - 2.7 = 7.2$

$\therefore z_c = 72 \times d = 7.2 \times 0.8 = 5.76m > 5m$

So, the entire pile will be subjected to lateral earth pressure with hydrostatic variation.



$\sigma_v K$ = $\gamma z K$
$= 18.2 \times 5 \times 0.8$
$= 72.8\ KPa$

$K = 0.8 \sim 1.0$ (should be more than that occurs for at rest condition)

$(T_u)_{soil} = [\sigma_v K_o \tan\delta] A_f$
$= [73 \tan 24°][\pi(0.8)(5)]$
$= 408\ KN$

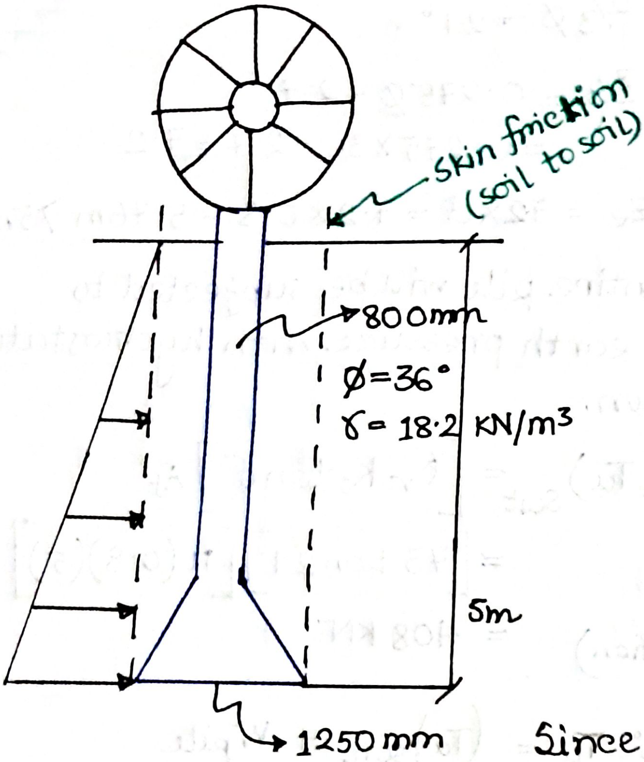
$\therefore T_u = (T_u)_{soil} + W_{pile}$
$= 408 + [\pi/4\ (0.8)^2 \times 5 \times 24]$
$= 408 + 60 = 468\ KN$

$\gamma_{concrete} = 24\ KN/m^3$

K → Lateral pressure coefficient to evaluate q_f for both sand & clay

Use K = 0.8 (both tension and comp.) for low-volume displacement pile.
= 1.0 for displacement piles.
(usually $K > K_o$ $(= 1 - \sin\phi)$)
use the same value of K for both sand & clay.

Q. What is the approximate ultimate pull out resistance T_u for a tension pile in a medium dense sand with $\phi = 36°$, $\gamma = 18.2\ KN/m^3$ and using an 800mm diameter concrete pile with a length of 5m (and with a ball at the top of dia 1.25m)



For $\phi = 36°$; $\frac{z_c}{d} = 0.275\phi - 2.7$
$= 0.275 \times 36 - 2.7 = 7.2$

$\therefore z_c = 7.2 \times 0.8 = 5.76m > 5m$

So the entire length of the pile will be subjected to lateral pressure of soil of hydraulic in nature.

$\sigma_z = \gamma D_f = \gamma z_c = 18.2 \times 5 = 91\ kPa$

$\sigma_h = K\sigma_z = 0.8 \times 91 = 72.8\ kPa$

$A_f = \pi(0.8)(5) = 12.57\ m^2$

Skin friction: $Q_f = [(\sigma_z K) \tan\delta] A_f$

Since a ball is at the top, so friction will occur between soil-to-soil (not soil-to-pile)

$\therefore \tan\delta = \tan\phi = \tan 36°$

$\therefore \phi_f = [72.8][\tan 36°][12.57] = 665\ KN$

Self weight:

$W_{pile} = \frac{\pi}{8}(0.8)^2(5 \times 24)$

$= 60\ KN$

$\gamma_{concrete} = 24\ KN/m^3$

End Bearing: This component will be derived by the shaded area of the pile "X-section"

$\therefore N_q = 38$; N_q corresponding angle.

ϕ = at the surrounding of the pile top (2B-upper) $= 36°$

$\therefore Q_b = [qN_q] A_b$

$= 91 * 38 * \frac{\pi}{4}[(1.25)^2 - (0.8)^2]$

$= 550\ KN$

$Q_{ult} = Q_b + Q_f + W_{pile}$

$= 550 + 665 + 60 = 1275\ KN$

(Ans.

Group Capacity of Piles

Ex 13·2
Varghese
Page 276

A group of friction piles in clay consists of 15 piles of 500 mm diameter (grouped as 5X3) spaced at 1m apart. If the undrained shear strength c of the clay is 0·3 kg/cm2 and the piles are 20m in length estimate the group capacity and its efficiency. [Note : the pile cap will extend 25cm around the piles and the pile cap will touch the soil but as the soil is clay the strength of the pile cap resting on the ground need not be considered.]

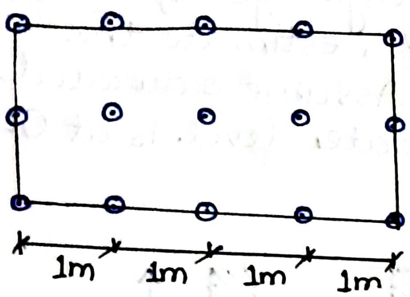
Solution: Step 1 : Capacity of each pile and that of the group :

Individual :

End bearing $Q_b = A_b\, c\, N_c = \left[\pi/4\,(0{\cdot}5)^2\right] * \left[0{\cdot}3 \times 100\right]$

$= 0{\cdot}13 \times 30 \times 9 = 0{\cdot}13 \times 270$

$= 35$ KN



$Q_f = \alpha * c * \Sigma A_f$

$= \left[0{\cdot}9 \times 30\right] * \left[\pi \times 0{\cdot}5 \times 20\right]$

$= 27 * 25 = 675$ KN

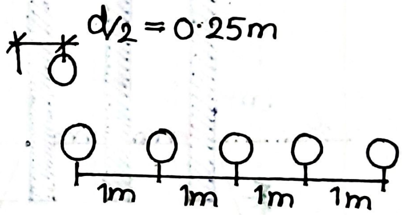
$c = 0{\cdot}3\ kg/cm^2$

$= 30\ KN/m^2$

$\alpha = 0{\cdot}9$ (soft clay)

$\therefore Q_u = n_p\,(Q_b + Q_f) = 15 * (35 + 675) = 10{,}650$

Step 2 : Capacity as a group :



group perimeter :

L : 5 piles @ 1m apart $= \left[4 \times 1 + \frac{0{\cdot}5}{2} \times 2\right] = 4{\cdot}5$m

B : 3 piles @ 1m apart $= \left[2 \times 2 + \frac{0{\cdot}5}{2} \times 2\right] = 2{\cdot}5$m

Projected area by perimeter for end bearing $= 4{\cdot}5 \times 2{\cdot}5 = 11{\cdot}25\ m^2$

Perimeter $= \left[4{\cdot}5 + 2{\cdot}5\right] \times 2 = 14$m

Depth Ratio $= \frac{D}{B} = \frac{20m}{2{\cdot}5m} = 8 > 2{\cdot}5$m

N_c from Skempton curve (P- 117, Figure 6·4 Varghese)

for $D/B = > 2{\cdot}5$; $N_c = 9{\cdot}0$

$\therefore Q_b = A_b\, c\, N_c = [11.25][30][9] = 3038$ KN

$Q_f = \alpha\, c\, \Sigma A_f = [1.0][30][14 \times 20] = 8400$ KN
↳ perimeter

here, $\alpha = 1.0$ [Soil-to-soil friction]

$Q_u = 3038 + 8400 = 11,438$ KN

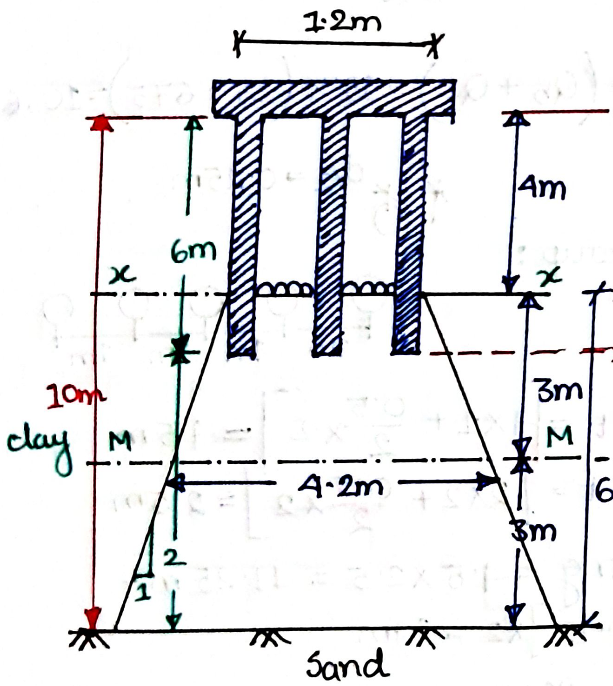
∴ Lesser of the above two Q_u is the group capacity,

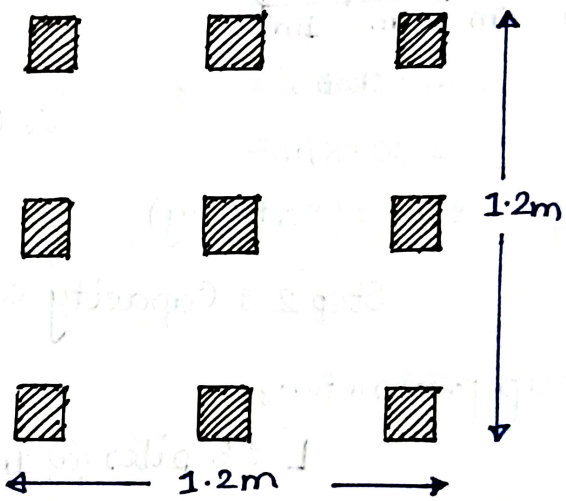
thus $Q_u = 10,650$ KN.

Settlement:

Ex 4.7
Page 93
Varghese

A group of nine piles of 200mm diameter spaced at 0.5m transfer a load of 400 KN into a 10m thick clay layer with sand below. It penetrates to a depth of 6m in the clay layer. If the clay is normally consolidated with a $LL = 40\%$, estimate the probable settlement of the pile group. Assume saturated water content is 39%.; $G_s = 2.7$ and the water level is at GL. Let, $\gamma = 20$ KN/m³.





[Assume raft level for analysis]

Step 1: Determinate characteristics of soil,

$$C_c = 0.009(LL-10)$$
$$= 0.009(40-10) = 0.27$$

$$e_o = \frac{wG_s}{S_r} \qquad S_r = 100\% = 1$$
$$= 0.39 \times 2.7 = 1.05$$

b) Calculate 2/3 depth XX, the assume level of raft where ΔP is released from the top of pile.

$$2/3\,L = \frac{2 \times 6}{3} = 4m \text{ from top of pile}$$

thickness of compressible layer for this pile arrangement,

$$H = 10 - 4 = 6m$$

mid depth $H/2 = 6/2 = 3m$; i.e, = 1m below the pile top

c) Enlarge area at C.G. $= [3/2 + 1.2 + 3/2]^2 = (4.2)^2 = 17.64m$

$$\Delta p = \frac{400}{(4.2)^2}$$

← it's not given in KPa; if so 1rst make convert it into KN by multiplying with a_o and divide it with new a_r

$$= 22.7\ KN/m^2$$

$$P_o = (20-10) \times (4m + 3.3) = 70\ KN/m^2$$

(4m → initial; 3.3 → mid depth)

(assumming submerged)

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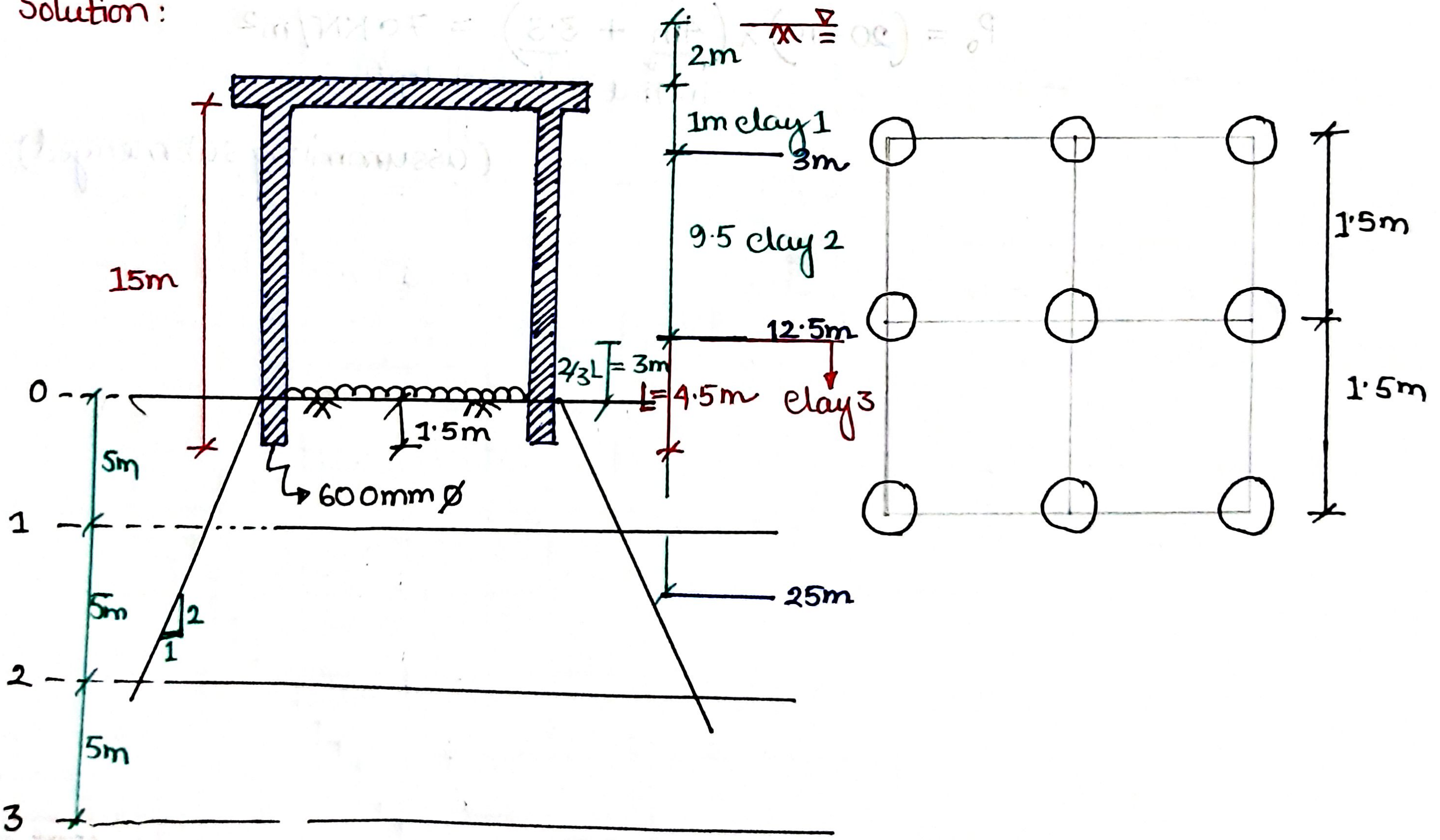
Q1 : A group of nine piles (each 600 mm diameter, 15m long and 1500mm spacing) is driven into layered clay-dominant soils to carry a design load of 12,000KN (dead load = 8000 KN and live load = 4000 KN). The piles are grouped as 3X3 with cut-off level at 2.0m below ground level and ground water table at GL. The underlying soil characteristics are as follows :

Depth from GL (m)	:	0~3.0	3.0~12.5	12.5~25.0
Cohesion, c (KN/m²)	:	25	40	125
Liquid limit, LL (%)	:	40	38	40
Moisture content, w (%)	:	28	27	25
Dry density, γ (KN/m³)	:	16.5	17.0	17.5
Saturated density, γ (KN/m³)	:	19.5	19.5	20.0
Specific gravity, Gs	:	2.68	2.69	2.71

Estimate settlement of the pile group under the sustained loading.

Solution :



Load transfer level at 0-0, 2/3L (L = transferrable clayey layer = clay-3)

$= 2/3 \times 4.5 = 3.0m.$

i.e, $4.5 - 3.5 = 1.5m$ up to the top of pile.

Initial stress at 0-0 (before

i) for 3.0m of clay-1 $= 19.5 \times 3 = 58.5$ KPa

ii) for 9.5m of clay-2 $= 19.5 \times 9.5 = 185.25$ KPa

iii) for 3.0m of clay-3 $= 20.0 \times 3 = 60.0$ KPa

iv) less $3+9.5+3 = 15.5m$ water $= 9.8 \times 15.5 = 152$ KPa

Effective P_o' at level 0-0 $= 58.5 + 185.25 + 60 - 152 = 152$ KPa

Effective P_o' at level 1-1 (5m below 0-0) $= 152 + [5 \times 20 - 5 \times 9.8] = 203$ KPa

Effective P_o' at level 2-2 (5m below 1-1) $= 203 + [5 \times 20 - 5 \times 9.8] = 254$ KPa

Effective P_o' at level 3-3 (5m below 2-2) $= 254 + 51 = 305$ KPa

Step 2: Consolidation increase of pressure assuming 2:1 distribution of various levels down to dead load.

Component of abutment load:

dead load = 8000 KN

$$\Delta P \text{ at (0-0) level} = 8000\left(\pi/4\left(1.5+1.5+\frac{0.6}{2}\times 2\right)^2\right) = 8000 \times \frac{\pi}{4}(3.6)^2$$

$$= 786 \text{ KPa}$$

$$\Delta P \text{ at (1-1) level} = \frac{786 \times \frac{\pi}{4}(3.6)^2}{\frac{\pi}{4}\left(3.6+\frac{5}{2}\times 2\right)^2} = 786 \times \left(\frac{3.6}{8.6}\right)^2 = 138 \text{ KPa}$$

$$\Delta P \text{ at (2-2) level} = \frac{786 \times (3.6)^2}{\left(3.6+\frac{10}{2}\times 2\right)} = 55.0 \text{ KPa} < 10\% \text{ of } \Delta P \text{ at (0-0)}$$

$$\Delta P \text{ at (3-3) level} = \frac{786 \times (3.6)^2}{\left(3.6+\frac{15}{2}\times 2\right)^2} = 29.4 \text{ KPa}$$

Step 3: P_o' and ΔP at mid heights:

i) Mid height of levels (0-0) & (1-1)

$$P_o' = \frac{152+203}{2} = 177.5 \text{ KPa}$$

$$\Delta P = \frac{786+138}{2} = 462 \text{ KPa}$$

$\therefore P_o' + \Delta p = 177.5 + 462 = 640$ KPa

ii) Mid heights of level (1-1) & (2-2)

$$P_o' = \frac{203+254}{2} = 229 \text{ KPa}$$

$$\Delta P = \frac{138+55}{2} = 96.5 \text{ KPa}$$

$$\therefore P_o' + \Delta P = 229 + 96.5 = 325.5 \text{ KPa}$$

iii) Mid heights of level (2-2) & (3-3)

$$P_o' = \frac{254+305}{2} = 280 \text{ KPa}$$

$$\Delta P = \frac{55.0+29.4}{2} = 42 \text{ KPa}$$

$$\therefore P_o' + \Delta P = 280 + 42 = 322 \text{ KPa}$$

Step 4 : Find e_o, C_c etc :

Soil will compress in clay-3, the S layer :

$$C_c = 0.009\,(LL-10) = 0.009 \times (40-10) = 0.27$$

$$e_o = \frac{wG_s}{S_r} = \frac{25}{100} \times \frac{2.71}{100} = 0.68$$

$S_r = 1.0$ for 100% Saturation.

Step 5 : Settlement Calculation:

$$S_1 = \left\{ \frac{C_c}{1+e_o} \log \frac{P_o' + \Delta P}{P_o'} \right\} \times H_1$$

$$= \left[\frac{0.27}{1+0.68} \log_{10} \frac{640}{177.5} \right] \times 5000 = 450 \text{ mm}$$

$$= 0.16 \times 0.56 \times 5000$$

Similarly, $S_2 = 0.16 \times \left\{ \log \frac{325}{229} \right\} \times 5000 = 0.16 \times 0.15 \times 5000$

$= 120$ mm

$S_3 = 0.16 \times \left\{ \log \frac{322}{280} \right\} \times 5000 = 0.16 \times 0.06 \times 5000$

$= 48$ mm

$$S_t = \Sigma S_i = 450 + 120 + 48 = 618 \text{ mm} = 61.8 \text{ cm}$$

(Ans.)