Tutorial 6
(Pile Foundation Solution)

1. A group of 9 piles 300 mm in diameter is driven in a square grid with spacing at 900 mm center to center. The piles are cast in site and are 10 m long. The unconfined compressive strength of the clay is 70 KN/m^2. Compute the allowable load on the pile group on the basis of shear failure criteria for a FOS of 2.5. Take adhesion factor as 1.

Solution;

Calculation of allowable load on the pile group.

a). Considering Individual failure for cohesive soil.

Given that;

No. of piles = 9 = n.

diameter (d) = 300 mm = 0.3 m.

length of pile (l) = 10 m.

FOS = 2.5.

Spacing = 900 mm = 0.9 m.

for given value of unconfined compressive strength = 70 KN/m^2, we have $C = 35$ KN/m^2.

Now;

[$Q_u = Q_b + Q_f$ [Static formula].]

$Q_{u(g)} = n \times Q_{u(s)}$.

$Q_{u(s)} = CN_c A_{b(s)} + \alpha \bar{C} A_{s(s)}$.

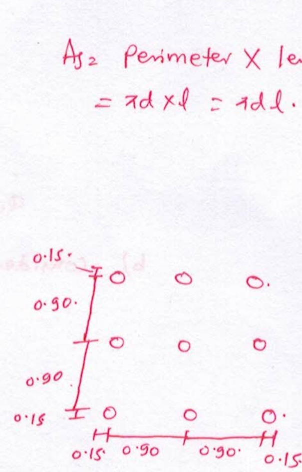
A_s = Perimeter X length.
$= \pi d \times l = \pi d l$.

$= 35 \times 9 \times \pi \times \frac{0.3^2}{4} + \{1 \times 35 \times \pi \times 0.3 \times 10\}$.

$= 22.266 + 329.867$.

$= 352.133$ KN

$\therefore Q_{u(g)} = 9 \times 352.133 = 3169.20$ KN.



b) Considering block failure.

$Q_{u(g)} = CN_c A_{b(g)} + \alpha \bar{C} A_{s(g)}$.

$= 35 \times 9 \times \{2.1 \times 2.1\} + \{1 \times 35 \times 4 \times (2.1) \times 10\}$.

$= 4329.15$ KN.

$L = \{0.90 \times 2\} + \{0.15 \times 2\}$.
$= 1.8 + 0.30 = 2.10$.

A_s = Perimeter x length.
$= 4L \times$ length.
(for square)

$A_b = L^2$ (for square).

Accept minimum value obtained from case a) and b).

$\therefore Q_{u(g)} = 3169.20$ KN.

$Q_a = \frac{Q_{u(g)}}{FOS} = \frac{3169.20}{2.50} = 1267.68$ KN.

2. A square pile group of 9 piles of 25 cm diameter is arranged with a pile spacing of 1m. The length of pile is 9m. Unit cohesion of clay is 75 KN/m^2. Neglecting the bearing at the tip of piles, determine the group capacity. Assume adhesion factor as 0.75.

Solution;

Given;

no. of piles = 9 (n)

diameter (d) = 25cm = 0.25m.

spacing = 1m.

length of pile (l) = 9m.

Cohesion (C) = 75 kN/m^2.

Adhesion factor (α) = 0.75.

Calculation of pile group capacity. for cohesive soils.

a) Considering individual failure;

$Q_u(g) = n \times Q_u(s)$.

$Q_u(s) = (C N_c A_b) + \alpha \bar{C} A_s$.

$(C N_c A_b) \rightarrow$ zero (0). As the bearing at the tip of piles is neglected.

$= \alpha \bar{C} A_s$.

$= 0.75 \times 75 \times [\pi \times 0.25 \times 9]$. $\{\because [\pi \times d \times l]\}$.

$= 397.61$ kN.

$Q_u(g) = n \times Q_u(s) = 3578.47$ kN.

b) Considering block failure;

$Q_u(g) = C N_c A_b(g) + \alpha \bar{C} A_s(g)$. ($C N_c A_b(g) \rightarrow 0$)

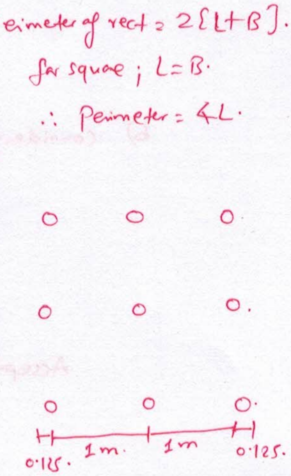
$= 0.75 \times 75 \times$ [perimeter $\times$ length].

$= 0.75 \times 75 \times [2[L+B] \times \text{length}]$.

$= 0.75 \times 75 \times 2 \times [2.25 + 2.25] \times 9$.

$= 4556.25$ kN.

Perimeter of rect = $2[L+B]$.
for square; $L = B$.
$\therefore$ Perimeter = $4L$.



$L = 2.25 = B$.

Adopt minimum value obtained from a) and b).

$\therefore Q_u(g) = 3578.47$ kN.

$$Q_a = \frac{Q_u(g)}{FOS}.$$

3. A group of 9 piles 12m long and 250mm diameter is to be arranged in a square form in a clayey soil with an average unconfined compressive strength of 60 KN/m². Work out the center to center spacing of the piles for a group efficiency factor of 1. Neglect bearing at the tip of piles. Take adhesion factor as 0.9.

Solution;

Given;

no. of piles (n) = 9.

length of pile (l) = 12m.

diameter of pile (d) = 250mm = 0.25m.

unconfined compressive strength = 60 kN/m².

$\therefore C = \frac{60}{2} = 30 \text{ kN/m}^2$.

η = Efficiency = 1.

$\alpha = 0.90$.

for cohesive soils;

a) considering individual failure;

$Q_u(g) = n \times Q_u(s)$.

$Q_u(s) = CN_c A_b + \alpha \bar{C} A_s$ → (Since bearing at the tip of pile is neglected.) [$CN_c A_b$ = 0]

$= \alpha \bar{C} A_s$

$= 0.90 \times 30 \times \pi \times 0.25 \times 12$.

$= 254.47$ kN.

$\therefore Q_u(g) = 9 \times 254.47 = 2290.22$ kN ——— a).

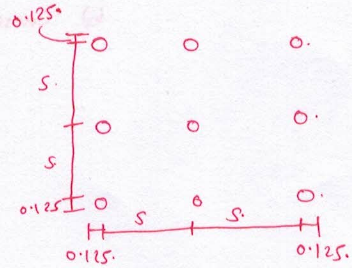
b) considering block failure;

$Q_u(g) = CN_c A_b(g) + \alpha \bar{C} A_s(g)$. [$CN_c A_b(g)$ = 0]

$= 0.90 \times 30 \times [4 \times [2S + 0.25] \times 12]$.

$= 1296 \cdot [2S + 0.25]$

$= 324 + 2592\,S$ ——— b).



Let spacing be 'S'.

Perimeter = $4 \times L$.

$= 4 \times [2S + 0.125 + 0.125]$.

$= 4 \times [2S + 0.25]$.

We have;

$\eta(g) = \frac{Q_u(g)}{n \times Q_u(s)} = \frac{324 + 2592S}{2290.22}$.

or, $1 = \frac{324 + 2529S}{2290.22}$.

$\therefore S = 0.76$m.

4. A circular pile group of 16 piles penetrates through an unconsolidated soil of 3.5m depth. The diameter of circular pile is 60cm and pile spacing is 800mm. The average unconfined compressive strength of the material is $60KN/m^2$ and the unit weight of soil is $16\ KN/m^3$. Compute the negative skin friction on the group. Take adhesion factor as 1.

Solution;

Given;

No. of piles(n) = 16.

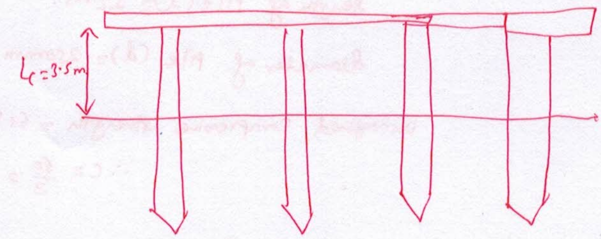
length of unconsolidated soil = l_c = 3.5m.

diameter(d) = 60cm = 0.60m.

Spacing(S) = 800mm = 0.80m.

Avg. compressive strength = $60kN/m^2$.

$\therefore c = \frac{60}{2} = 30kN/m^2$.



$\gamma = 16kN/m^3$.

$\alpha = 1$.

Calculation of -ve skin friction;

a) Considering individual failure;

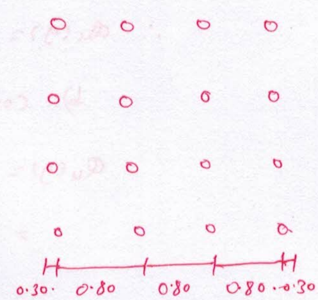
$Q_{NSF}(g) = n \times Q_{NSF}(s)$.

$Q_{NSF}(s) = \alpha \bar{c} A_s$. [friction को कुनै सहयोग यसमा End bearing को कुनै आउदैन).

$= 1 \times 30 \times [\pi \times 0.60 \times 3.50]$.

$= 197.92kN$.

$Q_{NSF}(g) = 197.92 \times 16 = 3166.72kN$.



b) Considering block failure;

$Q_{NSF}(g) = \alpha \bar{c} A_s(g) + \gamma L_c A_b(g)$.

$= 1 \times 30 \times [2 \times [3+3] \times 3.5] + [16 \times 3.5 \times 3 \times 3]$.

$= 1764kN$.

$\therefore L = (3 \times 0.80) + 0.30 + 0.30$

= 3m.

= B.

Negative skin friction को case मा सधैं highest of above two conditions लिनु पर्दछ ।

$\therefore Q_{NSF}(g) = 3166.72kN$.

5. Design a friction pile group to carry a load of 3000 KN including the weight of pile at a site where the soil is uniform clay to a depth of 20 m underlain by rock. Average unconfined compressive strength of the clay is 70 KN/m^2. Take FOS = 3 and adhesion factor as 0.4.

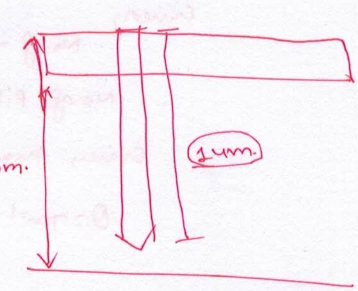
Solution;

Given;

load = 3000 KN.

Avg. unconfined compressive strength of clay = 70 KN/m^2.

$\therefore c = \frac{70}{2} = 35$ KN/m^2.



FOS = 3., $\alpha = 0.40$.

– Design गर्न भनेर सोचेको स्थितिमा हामीले diameter र length of pile assume गर्नेछौं। यो case मा हामीलाई friction pile design गर्न भनेर सोधेको छ, त्यसैले pile को end ले load लिन पाउँदैन। त्यसैले length assume गर्दा, layer thickness बराबरको assume गर्न पाइँदैन, त्यो भन्दा कम assume गर्नुपर्दछ। त्यति नै assume गर्यो भने end ले पनि load transfer गर्छ र त्यसलाई friction pile मात्र भन्न मिल्दैन।

– Design गर्न भनेर सोचेको स्थितिमा हाम्रो उद्देश्य pile no. र spacing पत्ता लगाउन पनि हुनेछ।

a) Considering individual failure.

$Q_{u(g)} = n \times Q_{u(s)}$.

$Q_{u(s)} = cN_c A_{b(s)} + \alpha \bar{c} A_{s(s)}$. [$cN_cA_{b(s)} = 0$]

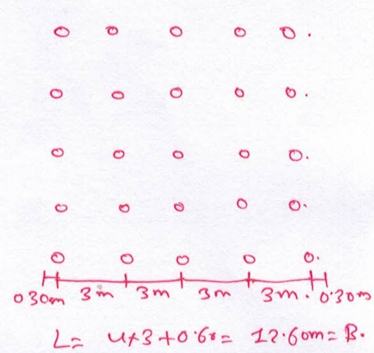
$= 0.40 \times 35 \times \pi \times 0.6 \times 14$. [Considering $d = 0.60$m, $l = 14$m].

$= 369.45$ KN.

$Q_a = \frac{Q_u}{F} = \frac{369.45}{3} = 123.15$ KN.

No. of piles required $= \frac{3000}{123.15} = 25$ piles.

(3000 → pile ले त्यो load थाम्न सक्छ भनेको नै allowable safe load को उपमा लिन सकिन्छ।)



Use 25 piles in square pattern with 5 piles in each row.

Spacing = 3d (min) Take 5d = 5×0.60 = 3m.

b) Considering group (block) failure;

$Q_{u(g)} = cN_c A_{b(g)} + \alpha \bar{c} A_{s(g)} = 0.40 \times 35 \times 4 \times 12.6 \times 14 = 9878.40$ KN. [$cN_cA_{b(g)} = 0$]

$Q_a = \frac{Q_{u(g)}}{FOS} = 3292.80$ KN > 3000 KN.

$L = 4 \times 3 + 0.6 = 12.60$m $= B$.

Also; $3292.80/25 = 131.71 > 123.15$ (O.K.).

6. Determine the group efficiency of rectangular group of piles with 4 rows and 3 piles per rows. The uniform pile spacing is 3 times pile diameter. If the individual pile capacity is 100 KN, what is the group capacity of pile according to this concept.

Solution;

Given;

No. of rows (m) = 4.

No. of piles per rows (No. of columns, n) = 3.

Given that spacing = 3d = 3d.

$\theta = \tan^{-1}\left[\frac{d}{s}\right] = \tan^{-1}\left[\frac{d}{3d}\right] = \tan^{-1}\left[\frac{1}{3}\right] = 18.43°$.

we have,

$$\eta_g = 1 - \frac{\theta}{90}\left[\frac{(n-1)m + (m-1)n}{mn}\right]$$

$$= 1 - \frac{18.43}{90}\left[\frac{(3-1)\times 4 + (4-1)\times 3}{12}\right]$$

$= 0.7098$

$= 70.98\%$

Again;

$$\eta_g = \frac{Q_u(g)}{N \times Q_u(s)} \times 100$$

(N → no. of piles.)

$$\text{or, } 0.7098 = \frac{Q_u(g)}{12 \times 100}$$

$\therefore Q_u(g) = 851.76\ \text{KN}$.

7. A 40 cm square pre-cast RCC pile is driven by 9m into a sandy bed. The SPT results performed in this ground are tabulated below.

Depth (m)	1.5	3	4.5	6	7.5	9	10.5	12
N-Value	4	6	12	12	20	24	35	39

Compute the factor of safety available if 1100 KN of compressible load is applied on this pile.

Solution;

$Q_u = 400 N_{cor} A_b + 2 \overline{N}_{cor} A_s$.

$= 400 \times (24) \times [0.4 \times 0.4] + 2 \overline{N}_{cor} \times$ [Perimeter x length].

(24) → Depth ९m छ त्यसैको लागि Table बाट value लिएको ।

$\overline{N}_{cor}$ को लागि Depth ९m दिएको छ, त्यति सम्मको Average लिने ।

$\overline{N}_{cor} = \dfrac{4+6+12+12+20+24}{6} = 13.$

$\therefore Q_u = 400 \times 24 \times 0.4 \times 0.4 + 2 \times 13 \times [4 \times 0.4 \times 9]$.

$= 1910.40 KN.$

Given that; $Q_a = 1100 KN$.

or, $\dfrac{Q_u}{FoS} = 1100.$

$\therefore FoS = 1.736.$

8. A concrete pile of circular cross section with diameter 400 mm is to be driven into a homogeneous mass of cohesionless soil. The pile is required to carry a safe load of 650 KN. The static CPT conducted at the site indicates the average value of q_c = 40kg/cm² along the pile and 120 kg/cm² below the tip level of the pile. Compute the length of the pile with a FOS of 2.50.

Solution:

Given:

$d = 400mm = 0.40m.$

$Q_a = 650 KN.$

$q_c = 40 kg/cm^2.$

$q_p = 120 kg/cm^2.$

$= 120000 KN/m^2.$

However, $q_p \leq 11000. KN/m^2.$

$\therefore q_p = 11000 kN/m^2.$

$FOS = 2.50.$

Now,

$Q_u = Q_b + Q_f.$

$= q_p \times A_b + A_s \times f_s.$

$= q_p \times A_b + A_s \times \frac{q_c}{2}.$

$= 11000 \times \frac{\pi \times 0.4^2}{4} + [\pi \times 0.4 \times l \times \frac{40}{2}]$

(→ यो value लाई पनि kN/m² मा राख्न मन परेमा यो 2 को ठाउँमा 200 राख्नुपर्छ।)

$= 1382.30 + 25.13 l.$

we have,

$FOS = 2.50.$

or, $\frac{Q_u}{Q_a} = 2.50.$

or, $\frac{1382.30 + 25.13 l}{650} = 2.50.$

$\therefore l = 9.66m.$

Take length of piles = 10m.

9. A 30cm square pile 15m long is driven in a deposit of medium dense sand ($\Phi = 36^o$, $N_\gamma = 40$, $N_q = 42$). The unit weight of sand is $15 KN/m^3$. What is the allowable load with a FOS of 3?

Solution;

we have;

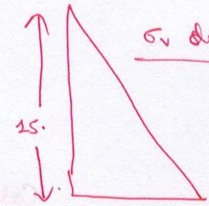
length of pile = $l = 15m$.

Cross-sectional Area $(A_b) = 0.30 \times 0.30$.

$\phi = 36^\circ$, $N_\gamma = 40$, $N_q = 42$.

$\gamma = 15 kN/m^3$.

FOS = 3.



for case of cohesionless soil.

$Q_u = Q_b + Q_f$.

$= (N_q - 1)\gamma D_f \times A_b + [K \bar{\sigma_v} \tan\delta \times A_s]$.

$= [41 \times 15 \times 15 \times 0.30 \times 0.30] + [(1) \times [\frac{225}{2}] \times \tan.[0.75 \times 36] \times 4 \times 0.3 \times 15.]$.

(1): for medium dense sand

$= 830.25 + 1031.789$

$= 1862.04$ KN.

calculation of allowable load;

$Q_a = \frac{Q_u}{FOS} = \frac{1862.04}{3}$.

$= 620.68$ KN.

10. A concrete pile of circular c/s with diameter 250 mm is driven int a saturated clay deposit. The undrained shear strength varies linearly with depth z and the relationship can be expressed as $c_u = 25 + 4z$ where c_u is in KN/m^2 and z is in m, measured form the ground surface. Determine the ultimate load capacity if the depth of penetration is 12m. Given that the adhesion factor is 0.80.

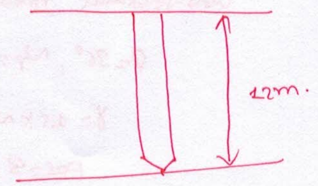
Solution;

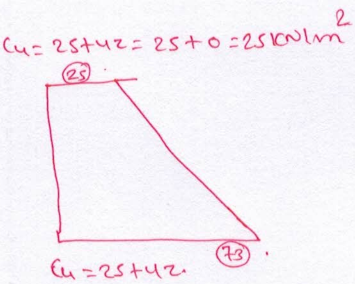
Given; $d = 250mm = 0.25m.$

$C_u = 25 + 4z.$

$l = 12m.$

$\alpha = 0.80.$





$= 25 + 4 \times 12.$

$= 25 + 48$

$= 73 KN/m^2.$

Calculations involved;

$Q_u = Q_b + Q_s.$

$= C N_c A_b + \alpha \bar{C} A_s$ → यो भनेको skin friction को part हो, त्यसैले shaft जहाँ हुँदैको छ, सबैको average लिनु पर्छ।

$= 73 \times 9 \times \pi \times \frac{0.25^2}{4} + \alpha \times \left[\frac{25+73}{2}\right] \times \pi \times 0.25 \times 12.$

CN_cA_b भनेको end bearing part हो, त्यसैले pile को tip जहाँ छ, c को value त्यहीँ नै हुन्छ।

$= 32.25 + 369.45$

$= 401.70 KN.$

11. A reinforced concrete pile of size 30cm * 30cm and 10m long is driven into dense sand extending to a greater depth. The average total unit weight of the sand is $18 KN/m^3$. Determine the allowable load on the pile by static formula is $\Phi = 32^o$. Use FOS = 2.5. Take $N_q = 25$. The water table is closed to the ground surface. If the average N_{cor} value is 15. Calculate the allowable load on the pile by SPT approach.

Solution:

Given,

Cross-sectional area $= A_b = 0.30^2 = 0.09 \, m^2$.

length of pile $= 10m = l$.

Given that for dense sand. $K = 2$.

$\gamma = 18 \, KN/m^3$.

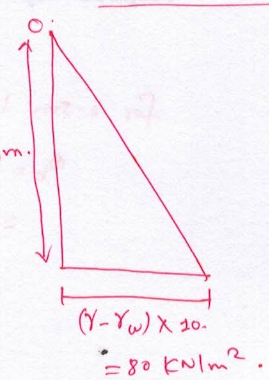
$\phi = 32^o$.

FOS = 2.50.

$N_q = 25$.

$N_{cor} = 15$.

for effective stress.



we have;

$Q_u = (N_q - 1)\, \sigma_v A_b + K \bar{\sigma}_v \tan\delta A_s$. → friction को part हो त्यो भएर pile को shaft भरी छ, त्यसको avg. value लिएको हो !

$= [(25-1) \times 0.30^2 \times [18-10] \times 10]$

$+ 2 \times \left[\frac{0+80}{2}\right] \times \tan \cdot [0.75 \times 32] \times 4 \times 0.3 \times 10]$.

End bearing part हो त्यसैले pile tip मा छ, σ_v को value त्यहिँ नै लिने ! यहाँ $8 \times 10 = 80$ हुन्छ ।

$= 600.21 \, KN$.

$\therefore Q_a = \frac{Q_u}{FOS} = \frac{600.21}{2.50} = 240.08 \, KN$.

Now;

$\bar{N}_{cor} = 15$.

$Q_u = 40 N_{cor} \left[\frac{L}{d}\right] A_b + 2 \bar{N}_{cor} A_s$.

Calculation of $40 N_{cor} \left[\frac{L}{d}\right] A_b$

$= 40 \times 15 \times \left\{\frac{10}{0.3}\right\} \times 0.3^2 \leq 400 \times N_{cor} \times A_b$.

$= 1800 \leq 540$.

$\therefore 40 N_{cor} \left[\frac{L}{d}\right] A_b$ must be limited to 540.

$\therefore Q_u = 540 + 2 \times 15 \times 4 \times 0.3 \times 10$. → perimeter × length.

$= 900 \, KN$.

$\therefore Q_a = Q_u / FOS = \frac{900}{2.50} = 360 \, KN$.

12. Two independent loading tests on 320mm diameter short bored piles in clay yielded the following results.

Embedded Length of pile (m)	Added load at failure
2.5	115
2.9	125

Assuming the adhesion is effective over the whole of the embedded length, estimate the mean cohesion of the soil and shaft adhesion factor to be used in extrapolating the test results to larger piles. The unit weight of soil and concrete are 19.2 KN/m^3 and 24 KN/m^3 respectively.

Solution;

for 2.5m length;

$Q_b = C N_c A_b$

$= C \times 9 \times \pi \times \frac{0.32^2}{4}$

$= 0.724 C$

$Q_f = \alpha \bar{C} A_s$

$= \alpha \times C \times 0.32 \times 2.5 \times \pi$

$= 2.513 \alpha C$

$Q_u = Q_b + Q_f$

or, $115 = 0.724C + 2.513\alpha C$ — a).

for 2.9m length;

$Q_b = C \times 9 \times \pi \times \frac{0.32^2}{4}$

$= 0.724 C$

$Q_f = \alpha \bar{C} A_s$

$= \alpha \times C \times \pi \times 0.32 \times 2.90$

$= 2.915 \alpha C$

$Q_u = Q_b + Q_f$

or, $125 = 0.724C + 2.915\alpha C$ — b).

On solving we get;

$\alpha = 0.343$

$C = 72.51$ KN/m^2.

13. A pre-cast concrete pile (35cm * 35cm) is driven by a single acting steam hammer. Estimate the allowable load using
    a) Engineering News Record Formula (FOS = 6)
    b) Hiley's Formula (FOS = 4)
    c) Danish's Formula (FOS = 4)

    Use the following data

    a) Weight of pile = 73.5 KN.
    b) Maximum rated energy = 3500 KN-cm.
    c) Weight of hammer = 35 KN.
    d) Length of pile = 15m.
    e) Efficiency of hammer = 0.8.
    f) Coefficient of restitution = 0.5.
    g) Weight of pile cap = 3 KN.
    h) No. of blows for last 25.4mm = 6.
    i) Modulus of elasticity of concrete = $2*10^7$ KN/m². Assume any other data if necessary.

Solution;

a) Using Engineering News Record formula.

$Q_u = \frac{E_n \eta_h}{s+C} = \frac{3500 \times 0.8}{\frac{2.54}{6} + 0.254} = 4133.86\,KN \Rightarrow Q_a = \frac{Q_u}{FOS} = \frac{4133.86}{6} = 688.97\,KN.$

6 वटा blow मा 25.4 mm,
1 blow मा $\frac{25.4}{6}$ mm.
$= \frac{2.54}{6}$ cm.

b). Using Hiley's formula;

$Q_u = \frac{wh\eta_b\eta_h}{s+C/2}$

$= \frac{E_n \eta_b \eta_h}{s+C/2}$

$= \frac{3500 \times \eta_b \times 0.8}{\frac{2.54}{6} + \frac{C}{2}}$ —a)

for η_b

$P = 73.5 + 3 = 76.50\,KN.$

$ep = 0.5 \times 76.50 = 38.25\,KN.$

$w = 35\,KN.$

$w < ep.$

$\therefore \eta_b = \frac{w+e^2p}{w+p} - \left[\frac{w-ep}{w+p}\right]^2$

$\left[\frac{35+0.5^2 \times 76.50}{35+76.50}\right] - \left[\frac{35-0.50 \times 76.50}{35+76.50}\right]^2$

$= 0.484.$

Calculation of C.

$C = C_1 + C_2 + C_3.$

$= \left[9.05 + 0.657\frac{D}{} + 3.55\right] \times \frac{R}{A}$

$= 0.018R = 0.018 Q_u.$

where; Q_u is in tonnes, for Q_u in KN.

$C = 0.0018 Q_u.$

Now; $Q_u = \frac{3500 \times 0.484 \times 0.8}{\frac{2.54}{6} + \frac{0.0018}{2} Q_u}$

Solving;

$Q_u = 1016\,KN.$

$\therefore Q_a = \frac{Q_u}{4} = 254\,KN.$

c) Using Danish's formula;

$Q_u = \frac{(wh) \times \eta_h}{s + S_0/2}$

$= \frac{3500 \times 0.8}{\frac{2.54}{6} + 0.5 S_0} = \frac{2800}{0.423 + 0.5S_0}$

where;

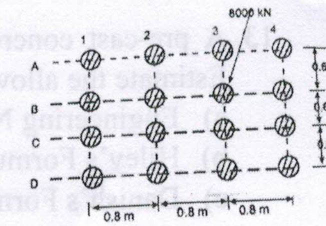
$S_0 = \sqrt{\frac{2\eta_b (wh) D}{AE}}$

$= \sqrt{\frac{2 \times 0.8 \times 3500 \times 1500}{35 \times 35 \times 2 \times 10^7 \times 10^{-4}}} = 1.85\,cm.$

$\therefore Q_u = \frac{2800}{0.423 + 0.5 \times 1.85} = 2077.2\,KN.$

$Q_a = \frac{Q_u}{4} = \frac{2077.20}{4} = 519.30\,KN$

14. From the following figure of pile group, determine a load carried by pile D1 and D4 if the resultant of the load on the pile group falls exactly on pile B3. The load on the pile group is 8000 kN. Assume that the pile cap is rigid.



Solution;

We have;

$$Q_i = \frac{Q}{n} \pm \frac{M_y \times x}{\Sigma x^2} \pm \frac{M_x \times y}{\Sigma y^2} \quad \text{--- a)}$$

From fig;

$e_x = 0.4\text{m}$

$e_y = 0.3\text{m}$

$M_y = Q \times e_x = 0.4 \times 8000 = 3200\text{kN}$

$M_x = Q \times e_y = 0.3 \times 8000 = 2400\text{kN}$

$$\Sigma x^2 = 2 \times [1.2^2 + 1.2^2 + 1.2^2 + 1.2^2] + 2 \times [0.4^2 + 0.4^2 + 0.4^2 + 0.4^2]$$

$= 11.52 + 1.28$

$= 12.80$

$$\Sigma y^2 = 2 \times [0.9^2 + 0.9^2 + 0.9^2 + 0.9^2] + 2 \times [0.3^2 + 0.3^2 + 0.3^2 + 0.3^2]$$

$= 6.48 + 0.72$

$= 7.20$

from a)

$$Q_i = \frac{8000}{16} \pm \frac{3200 \times x}{12.80} \pm \frac{2400 \times y}{7.20}$$

for D1 pile.

$x = -1.20\text{m}, y = -0.90\text{m}$

$$Q_{D1} = \frac{8000}{16} + \frac{3200 \times (-1.20)}{12.80} + \frac{2400 \times (-0.90)}{7.20}$$

$= -100\text{kN}$

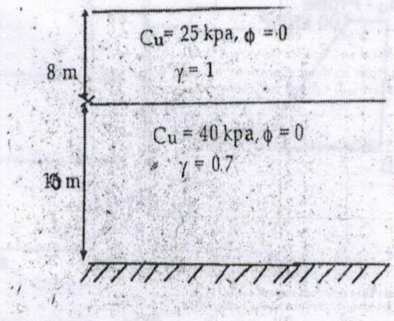
for D4 pile.

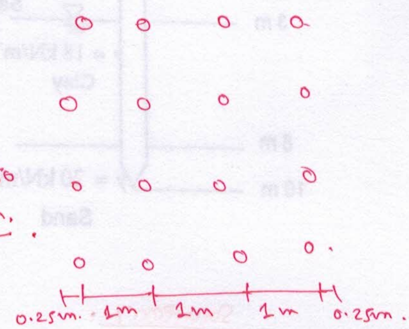
$x = 1.20\text{m}, y = -0.90\text{m}$

$$Q_{D4} = \frac{8000}{16} + \frac{3200 \times 1.20}{12.80} + \frac{2400 \times (-0.90)}{7.20}$$

$= 500\text{kN}$

15. A group of 16 piles, 4 in each row was installed in a layered clay deposit. The diameter of each pile is 500mm and their center to center spacing is 1m. The length of the pile group is 18m. Estimate the safe load capacity of a group with FOS of 2.5. The adhesion factor between pile and soil in each soil layer are shown in figure below.





Solution;

a). Considering individual failure;

$Q_u(g) = n \times Q_u(s)$.

$Q_u(s) = Q_b + Q_f$.

Calculation of Q_b.

यो प्रश्नको end bearing को कुरा हो। End bearing pile को Tip मा गई हेर्दा layer 2 मा छ, त्यसैले 'c' को ठाउँमा c_2 अर्थात layer 2 को 'c' को value लिनुपर्छ।

$Q_b = C N_c A_b$.

$= c_2 \times 9 \times \pi \times \frac{0.5^2}{4}$.

$= 40 \times 9 \times \pi \times \frac{0.5^2}{4}$

$= 70.88$ KN.

Calculation of Q_f.

यो प्रश्नको Skin friction को कुरा हो पुन pile को shaft संग associated छ। pile को shaft दुवै layer मा भएको हुनाले दुवै layer लिनुपर्छ।

$Q_f = \alpha \bar{c} A_s$.

$= [\alpha_1 c_1 \pi d l_1 + \alpha_2 c_2 \pi d l_2]$.

$= [1 \times 25 \times \pi \times 0.5 \times 8] + [0.70 \times 40 \times \pi \times 0.50 \times 10]$.

$= 753.98$ KN.

$\therefore Q_u(s) = Q_b + Q_f$.

$= 824.86$ KN.

$Q_u(g) = n \times Q_u(s) = 13197.79$ KN.

$[\because n = 9]$

b). Considering block failure;

$Q_u(g) = C N_c A_b(g) + \bar{\alpha} \bar{c} A_s(g)$.

$= 40 \times 9 \times [3.5 \times 3.5] + \left[\frac{\alpha_1 L_1 + \alpha_2 L_2}{L_1 + L_2}\right] \times \left[\frac{L_1 C_1 + L_2 C_2}{L_1 + L_2}\right] \times [4 \times 3.50 \times 18]$.

$= 4410 + [0.833 \times 33.33 \times 252]$.

$= 11406.50$ KN.

Taking lower values from case a) and case b).

we have;

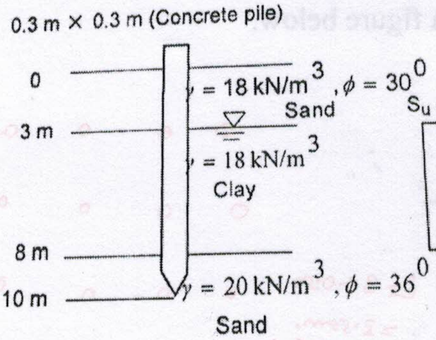
$Q_u(g) = 11406.50$ KN.

$Q_a = \frac{Q_u(g)}{FOS}$.

$= \frac{11406.50}{2.50}$

$= 4562.60$ KN

16. Determine the ultimate load of the concrete pile as shown in figure. Use necessary charts provided.



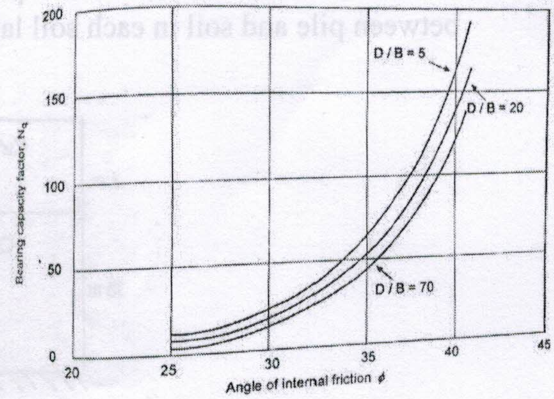


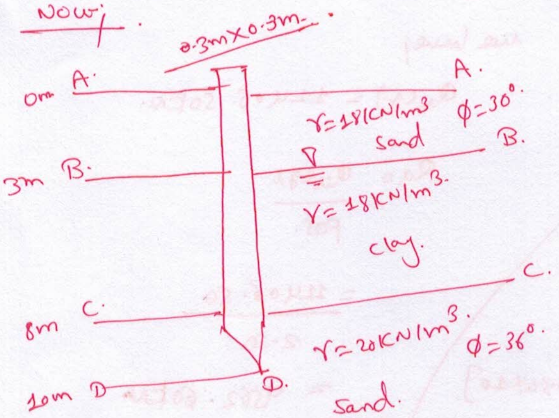
Fig.7.6 Berezantsev's bearing capacity factor, Nq

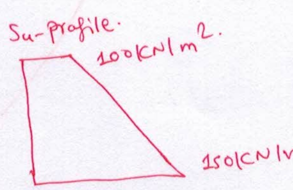
Solution:-

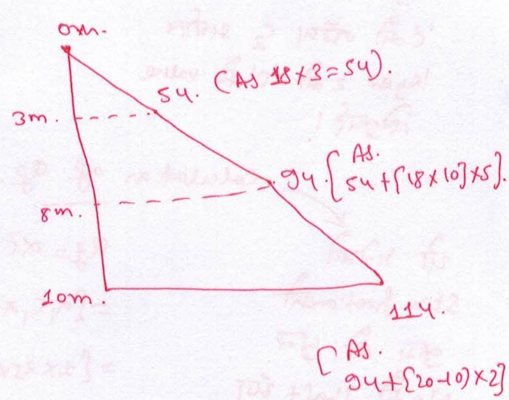
सबैभन्दा माथिल्लो layer sand हो अर्थात् cohesionless soil हो, बिचको layer clay हो त्यो cohesive soil हो जसमा C को value depth अनुसार varying छ। अन्तिम layer sand हो पुन cohesionless soil हो। यसरी पहिलो (माथिल्लो) र अन्तिम layer को लागि pile capacity for cohesionless soil को formula लगाउनु पर्छ (भने बिचको लागि pile capacity for cohesive soil को formula लगाउनु पर्छ!

Note: अन्तिम layer को case मा मात्र pile को end ले load transfer गर्ने भएकाले अरु माथिल्लो layer मा end bearing portion लाई zero लिएर हिसाब गर्नु पर्दछ। त्यसमा skin friction ले मात्र contribute गर्छ।

Now:-







for (0–3) m.

$Q_s = K\bar{\sigma}_v A_s \tan\delta$.

$A_s = 4 \times 0.3 \times 3 = 3.6\, m^2$.

$\delta = 0.75\phi = 0.75 \times 30 = 22.5°$ [for $\phi = 30°$, $K = 1$).

$\bar{\sigma}_v = \frac{54}{2} = 27\, kN/m^2$.

$\therefore Q_s = 3.6 \times 1 \times 27 \times \tan 22.5° = 40.26\, kN$.

for (3–8) m.

$Q_s = \alpha \bar{c} A_s$.

$= \alpha \times \left[\frac{100+150}{2}\right] \times 4 \times 0.3 \times 5$.

Taking $\alpha = 0.85$ for $L/B = \frac{5}{0.3}$

we have;

$Q_s = 0.85 \times 125 \times 20 \times 0.3$

$= 637.5\, kN$.

for (8–10) m.

$Q_b = (N_q - 1)\, \sigma_v \times A_b$.

Here; $D/B = \frac{10}{0.3} = 33$.

$\phi = 36°$.

$N_q = 56$.

(End bearing capacity निकाल्दा pileको tipले जहाँ हुन्छ, त्यहिँको value लिने हो!)

$\therefore Q_b = (56-1) \times [114] \times 0.3 \times 0.3$.

$= 564.30\, kN$.

$\therefore Q_f = K\bar{\sigma}_v \tan\delta \times A_s$.

for $\phi = 36°$; $K = 2$

(Skin frictionको गर्दाको value दुवै भएकोले shaft को contact मा आउने valueको average लिएको हो !).

$\therefore Q_f = 2 \times \left(\frac{94+114}{2}\right) \times \tan[0.75 \times 36] \times 4 \times 0.3 \times 2$.

$= 254.4\, kN$.

Total capacity; $Q_u = 40.26 + 637.50 + 564.30 + 254.40$.

$= 1496.46\, kN$.