Applied Geo Technical Engineering VTU Q Paper June/July-2023

Question paper and solution

CBCS SCHEME

USN

18CV62

Sixth Semester B.E. Degree Examination, June/July 2023

Applied Geotechnical Engineering

Time: 3 hrs.

Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of IS:6403 is permitted.

Module-1

1 a. What is subsurface exploration? Enumerate the objectives of subsurface exploration. (10 Marks)

b. Explain seismic refraction method with neat sketch. What are its limitations? (10 Marks)

OR

2 a. Establish the location of ground water in a Clayey strata, water in bore is bailed out to a depth of 12m below ground surface and rise of water recorded at 24 hr interval are $h_1 = 60cm$, $h_2 = 55cm$, $h_3 = 50cm$. (10 Marks)

b. What are the methods available for dewatering? Explain dewatering by electro osmosis method with neat sketch. (10 Marks)

Module-2

3 a. Derive Boussinesq expression for vertical stress due to concentrated load. When r/z ratio is zero what is the value of Boussinesq influence co-efficient? (10 Marks)

b. A concentrated load of 50 kN acts on the surface of a homogeneous soil mass of large extent. Determine the stress intensity at a depth of 5m, directly under the load and at a horizontal distance of 2.5m. Use Boussinesq analysis. (08 Marks)

c. What is Isobar? (02 Marks)

OR

4 a. There is a layer of soft clay 4m thick under a newly constructed building. The overburden pressure at the centre of the clay layer is 300 kN/m^2. Compute the settlement if there is an increase in pressure due to construction of 1000 kN/m^2. Take $C_C = 0.5$, $G = 2.7$ and water content $\omega = 50\%$. (10 Marks)

b. Explain the classification of foundation settlement. What are the other causes of settlement? (10 Marks)

Module-3

5 a. What are the causes of slope failure? List and enumerate the types of failure in finite slopes. (10 Marks)

b. A new canal is excavated to a depth of 5m below group level through a soil having the characteristics as, $C = 14\ kN/m^2$, $\phi = 15°$, $e = 0.8$ and $G = 2.7$. The slope of banks is 1 in 1. If the Taylors stability number is 0.083, calculate the factor of safety with respect to cohesion when the canal runs full. If it is suddenly emptied, what will be the factor of safety? Take Taylor's stability number as 0.122. (10 Marks)

1 of 2

18CV62

OR

6 a. Explain the procedure of Culmann's graphical method for active earth pressure. **(10 Marks)**

b. A retaining wall with a stratified backfill and a surcharge load is shown in the Fig.Q6(b). Draw the earth pressure diagram. Also estimate the resultant thrust on the wall and its position.

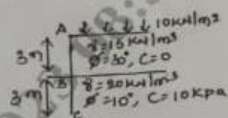

Fig.Q6(b)

(10 Marks)

Module-4

7 a. Explain standard penetration test and its correction. **(10 Marks)**

b. A strip footing 2m wide carries a load intensity of 400 kN/m^2 at a depth of 1.2m in sand. The saturated unit weight of sand is 19.5 kN/m^3 and unit weight above water table is 16.8 kN/m^3. The shear strength parameters are $C = 0$ and $\phi = 35°$. Determine the factor of safety with respect to shear failure for the following cases of location of water table.

i) Water table is 4 m below Ground Level.

ii) Water table is 2.5 m below Ground Level. **(10 Marks)**

OR

8 a. Explain the effect of water table on bearing capacity of soil. **(10 Marks)**

b. A square footing 2.5m × 2.5m is built on homogeneous bed of sand of density 19 kN/m^3 and having angle of shearing resistance of 36°. The depth of foundation is 1.5m below ground surface. Calculate safe load that can be applied on the footing with factor of safety 3. Take bearing capacity factors as $N_c = 27$, $N_q = 30$ and $N_\gamma = 35$. **(10 Marks)**

Module-5

9 a. List the classification of piles based on different criteria. Explain with neat sketch classification of piles based on function. **(10 Marks)**

b. In a 16 pile group, the pile diameter is 45 cm and centre to centre spacing of the square group is 1.5m. If $C = 50\ kN/m^2$, determine whether the failure would occur with the pile acting individually or as a group? Neglect bearing at the tip of the pile. All piles are 10m long. Take m = 0.7 for shear mobilization around each pile. **(10 Marks)**

OR

10 Write short notes on :

a. Efficiency of pile group

b. Negative Skin friction

c. Under-reamed pile

d. Settlement of pile group **(20 Marks)**

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1. **A. What is subsurface exploration? And enumerate the objectives of soil exploration?**

Answer:
"The field and laboratory investigations required to obtain necessary data regarding the soil, for proper design and successful construction of any structure at the site are collectively called soil exploration."
Objectives of soil exploration

Soil investigations are done to obtain the information that is useful for one or more of the following purposes:

1. To know the geological condition of rock and soil formation.

2. To establish the groundwater levels and determine the properties of water.

3. To select the type and depth of foundation for proposed structure

4. To determine the bearing capacity of the site.

5. To estimate the probable maximum and differential settlements.

6. To predict the lateral earth pressure against retaining walls and abutments.

7. To select suitable construction techniques

8. To predict and to solve potential foundation problems

9. To ascertain the suitability of the soil as a construction material.

10. To determine soil properties required for design

11. Establish procedures for soil improvement to suit design purpose

12. To investigate the safety of existing structures and to suggest the remedial measures.

13. To observe the soil the soil performance after construction.

14. To locate suitable transportation routes.

1.B. Explain seismic refraction method with neat sketch. And What are its limitations?
Answer:
Seismic refraction method:

Based on the fact that seismic waves have different velocities in different types of soils (or rock) and besides the wave refract when they cross boundaries between different types of soils.

Shock waves are created into the soil by exploding small charges or by striking a plate on the soil with a hammer. These waves are classified as direct, reflected and refracted waves.

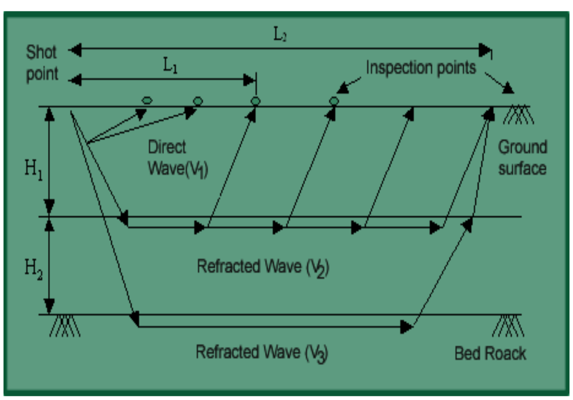
Radiating shock waves are picked up by geophones, where the time of travel gets recorded.

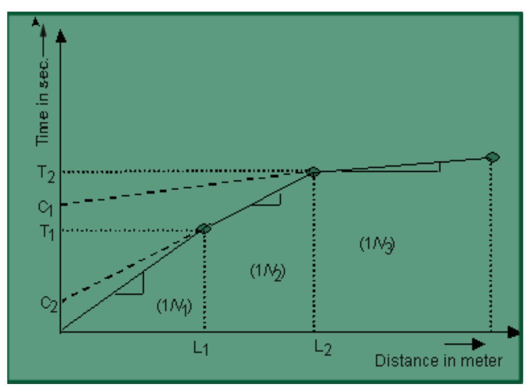
Either a number of geophones are arranged along a line or shock producing device is moved away from the geophone.

The direct wave travel in approximately straight line from the source of impulse. The reflected and refracted wave undergoes a change in direction when they encounter a boundary separating media of different seismic velocities.

Results are plotted as a graph shown in figure below.

Suited for the shallow explorations for civil engineering purpose.



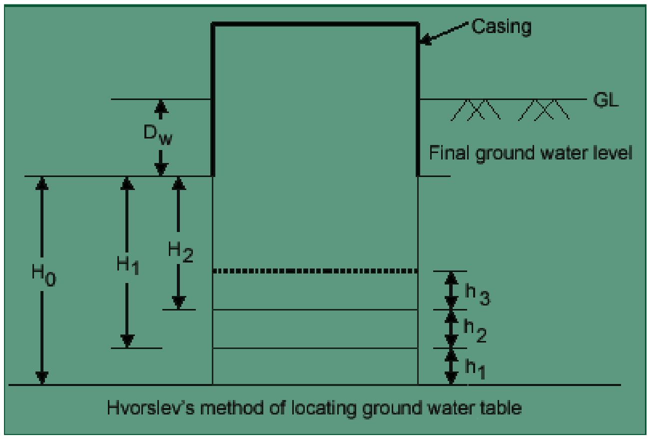


Seismic refraction method

Graph of Time vs Distance

2. **A. Establish the location of ground water in a clayey strata, water in box hole was bailed out to a depth of 12 m below ground surface and rise of water was recorded at 24 hour interval. h1= 60 cm, h2= 55 cm, h3= 50 cm.**

Answer:



Hvorslev's method of locating ground water table

Now from the fig.

$H_o - H_1 = h_1$, $H_1 - H_2 = h_2$, $H_2 - H_3 = h_3$

Let $t_1 - t_o = t_2 - t_1 = t_3 - t_2$,etc. = Δt

The depths H_1, H_2, H_3 of the water level in the casing from the normal water table D_W level can be computed as follows,

$H_o = h_1^2 (h_1 - h_2)$ $H_1 = h_2^2 (h_1 - h_2)$ $H_o = h_3^2 (h_2 - h_3)$

let the corresponding depths of the water table level below the ground surface be h_{w1}, h_{w2}, h_{w3}, etc. we have

$h_{w1} = H_w - H_o$

$h_{w2} = H_w - (h_1 + h_2) - H_2$

$h_{w3} = H_w - (h_1 + h_2 + h_3) - H_3$

where, H_w is the depth of water table in the casing from the ground surface at the start of the test.

Normally $h_{w1} = h_{w2} = h_{w3} = h_w$; if not average value gives h_w.

$H_o = h_1^2/(h_1 – h_2) = .0.8^2 / (.80 – .70) = 6.4$ m
$H_1 = h_2^2/(h_1 – h_2) = .70^2 / (.80 – .70) = 4.9$ m
$H_2 = h_3^2/(h_2 – h_3) = .60^2 / (.70– .60) = 3.60$ m
1st day $h_{w1} = H_w – H_o = 8.6$ m
2nd day $h_{w2} = H_w – (h_1 + h_2) - H_1 = 8.6$ m
3rd day $h_{w3} = H_w – (h_1 + h_2 + h_3) - H_2 = 9.3$ m
$h_w = (h_{w1} + h_{w2} + h_{w3})/3 = 8.83$ m

2. **B. What are the different methods available for dewatering? Explain dewatering by electro osmosis method with neat sketch.**

Answer:

Methods of dewatering

The ground water table may be lowered by the following methods:
(1)Ditches and sumps (2) Well point system (3) Shallow well system (4) Deep well system (5)

Vacuum method (6) Electro-osmosis method

Electro-Osmosis method
Electro-osmosis is defined as "the movement of water (and whatever is contained in the water) through a porous media by applying a direct current (DC) field". It is the only effective method of dewatering in deep clay soils.

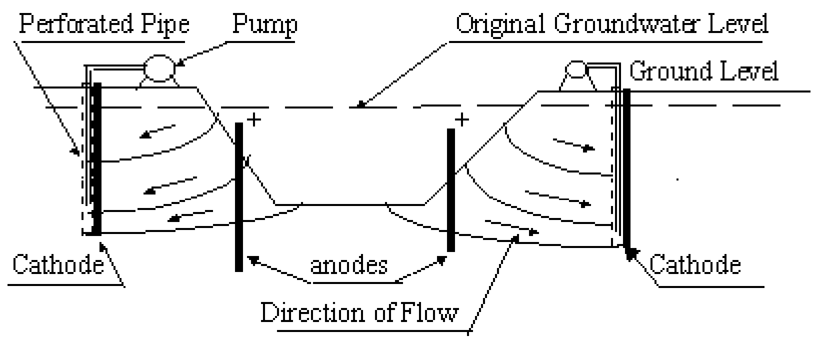


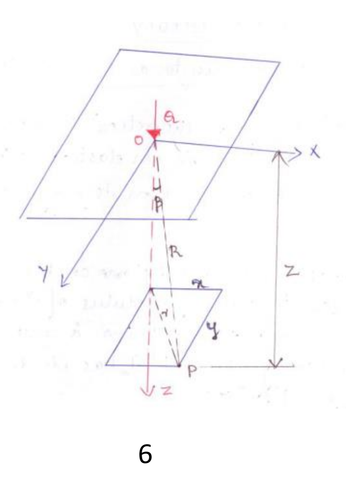
Fig. 8.8 Control of Groundwater by Electro-Osmosis Methods

As the surface of fine grained soil particles causes negative charge, the positive ions in solution are attracted towards the soil particles and concentrate near the surfaces. Upon application of the
electro motive force between two electrodes in a soil medium the positive ions adjacent to the soil particles and the water molecules attached to the ions are attracted to the cathode and are repelled by the anode. The free water in the interior of the void spaces is carried along to the cathode by viscous flow. By making the cathode a well, water can be collected in the well and then pumped out.

3. **A. Derive Boussinesq's expression for vertical stress due to concentrated load. When r/z ratio is zero, what is the value of Boussinesq influence coefficient.**

Answer:

Vertical stress due to concentrated load using Boussinesq's analysis



using logarithmic stress function, polar stress σ_R at $P(x, y, z)$ is

$$\sigma_R = \frac{3}{2\pi} \frac{Q \cos\beta}{R^2}$$

R = polar distance b/w origin O & point P

β = angle which line OP makes with vertical.

$$R = \sqrt{x^2+y^2+z^2}$$

$$r^2 = x^2 + y^2 \Rightarrow R = \sqrt{r^2+z^2}$$

$$\sin\beta = \frac{r}{R} \quad \& \quad \cos\beta = \frac{z}{R}.$$

vertical stress σ_z at P is $\sigma_z = \sigma_R \cos^2\beta$.

$$= \left(\frac{3}{2\pi} \frac{Q\cos\beta}{R^2}\right)\cos^2\beta$$

$$= \frac{3Q}{2\pi} \frac{\cos^3\beta}{R^2} = \frac{3Q}{2\pi} \frac{(z/R)^3}{R^2}$$

$$= \frac{3Q}{2\pi} \frac{z^3}{R^5}$$

$$= \frac{3Q}{2\pi} \times \frac{1}{z^2} \times \frac{z^5}{R^5}$$

$$= \frac{3Q}{2\pi} \times \frac{1}{z^2} \left[\frac{z^5}{(r^2+z^2)^{5/2}}\right]$$

$$= \frac{3Q}{2\pi} \times \frac{1}{z^2} \left[\frac{1}{\left[1+\left(\frac{r}{z}\right)^2\right]^{5/2}}\right]$$

$$\sigma_z = I_B \times \frac{Q}{z^2}$$

where $$I_B = \frac{3}{2\pi\left[1+\left(\frac{r}{z}\right)^2\right]^{5/2}}$$

I_B = Boussinesq influence coefficient for vtl stress.

3. B. A concentrated load of 20kN acts on the surface of a homogeneous soil mass of large extent. Determine the stress intensity at a depth of 6m, directly under the load and at a horizontal distance of 2.5m. Use Boussinesq analysis.

Answer:

Ans:-

$$\sigma_z = \frac{3Q}{2\pi} \times \frac{1}{z^2} \times \left[\frac{1}{\left(1+\left(\frac{r}{z}\right)^2\right)^{5/2}}\right]$$

At point P, z=6m, Q=2000 KN, r=0.

$$\sigma_z = \frac{3 \times 2000}{2\pi} \times \frac{1}{6^2} \times \left[\frac{1}{\left(1+\left(\frac{0}{6}\right)^2\right)^{5/2}}\right]$$

$$\sigma_z = 26.52\ kN/m2$$

At point R, z=6m, Q=2000 KN, r=5m.

$$\sigma_z = \frac{3 \times 2000}{2\pi} \times \frac{1}{6^2} \times \left[\frac{1}{\left(1+\left(\frac{5}{6}\right)^2\right)^{5/2}}\right]$$

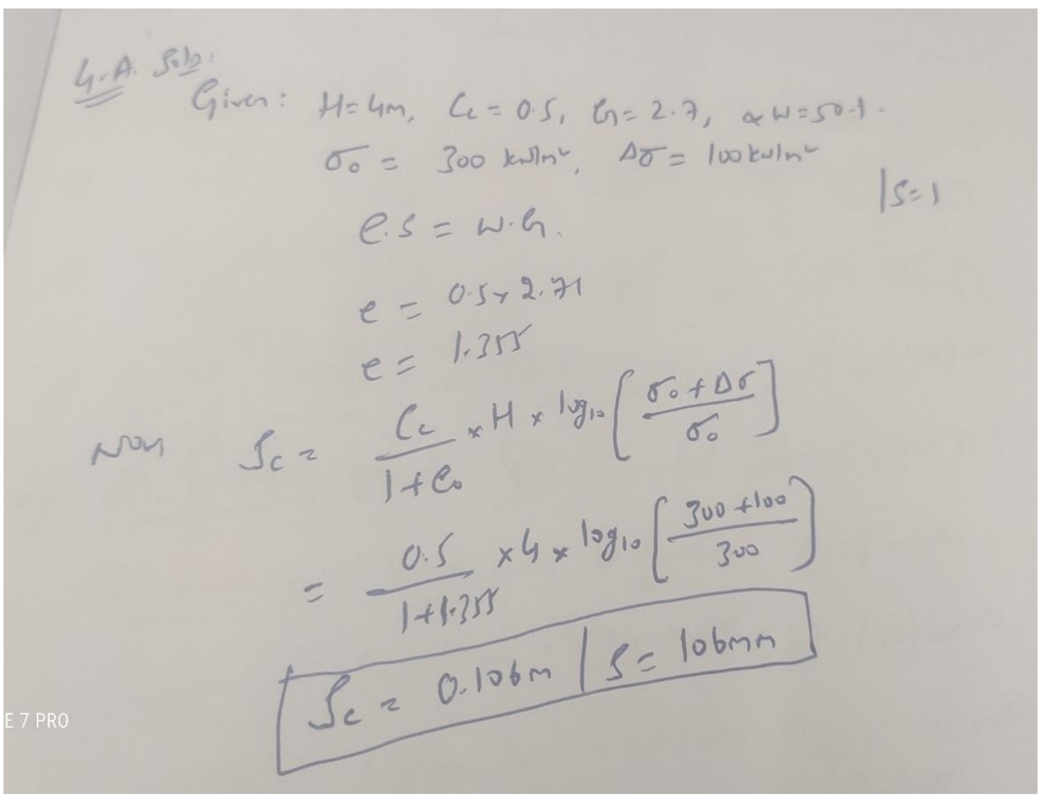
$$\sigma_z = 7.097\ kN/m2$$

3.C. **What is Isobar?**

Answer: **Isobar:-** Isobar is a curve joining the points of equal stress intensity. It is a spatial curved surface of the shape of an electric bulb or an onion. They are useful for determining the effect of the load on the vertical stress at various points. It is generally assumed that an isobar of 0.1Q forms a pressure bulb. The area outside the pressure bulb is assumed to have negligible stresses.

4. **A. There is a layer of soft clay 4m thick under a newly constructed building. The overburden pressure at the center of the clay layer is 300kN/m^2. Compute the settlement if there is an increase in pressure due to construction 100kN/m^2. Take Cc=0.5, G= 2.7, and w= 50%.**

Answer:


4.A. Soln:
Given: $H = 4m$, $C_c = 0.5$, $G = 2.7$, $w = 50\%$.
$\sigma_0 = 300\ kN/m^2$, $\Delta\sigma = 100\ kN/m^2$
$S = 1$
$e \cdot S = w \cdot G$
$e = 0.5 \times 2.71$
$e = 1.355$
Now $S_c = \frac{C_c}{1+e_0} \times H \times \log_{10}\left[\frac{\sigma_0 + \Delta\sigma}{\sigma_0}\right]$
$= \frac{0.5}{1+1.355} \times 4 \times \log_{10}\left[\frac{300+100}{300}\right]$
$S_c = 0.106m$ | $S = 106mm$

4. B. Explain the classification of foundation settlement. What are the other causes of settlement.

Answer:

* Foundation Settlement / Types of Settlement

Components of Total Settlement

The total settlement of a foundation comprises three parts as follows

$$S = S_e + S_c + S_s$$

where S = Total Settlement

S_e = Elastic / immediate Settlement / primary

S_c = Consolidation Settlement

S_s = Secondary Settlement.

* Factors influencing Settlement :-

1. Elastic properties of Soil
2. Shape of footing
3. Rigidity of footing
4. Contact pressure
5. width of footing
6. Compressibility characteristics of Soil
7. Initial condition of Soil
8. Degree of Saturation
9. Time available for movement
10. Thickness of [illegible] layer

5. **A. What are the causes of slope failure? List and enumerate the types of failure in finite slopes.**

Answer:

Causes of Slope failure
1. Erosion: The wind and flowing water causes erosion of top surface of slope and makes the slope
steep and thereby increase the tangential component of driving force.
2. Steady Seepage: Seepage forces in the sloping direction add to gravity forces and make the slope
susceptible to instability. The pore water pressure decreases the shear strength. This condition is critical
for the downstream slope.
3. Sudden Drawdown: in this case there is reversal in the direction flow and results in instability of
side slope. Due to sudden drawdown the shear stresses are more due to saturated unit weight while the
shearing resistance decreases due to pore water pressure that does not dissipate quickly.
4. Rainfall: Long periods of rainfall saturate, soften, and erode soils. Water enters into existing cracks
and may weaken underlying soil layers, leading to failure, for example, mud slides.
5. Earthquakes: They induce dynamic shear forces. In addition there is sudden buildup of pore water
pressure that reduces available shear strength.
6. External Loading: Additional loads placed on top of the slope increases the gravitational forces that
may cause the slope to fail.
7. Construction activities at the toe of the slope: Excavation at the bottom of the sloping surface
will make the slopes steep and thereby increase the gravitational forces which may result in slope
failure.
Types of failure
Broadly slope failures are classified into 5 types as
1. Rotational Failure
A. Face (Slope) failure
B. Toe failure
C. Base failure
2. Translational Failure
3. Compound Failure
4. Wedge Failure
5. Miscellaneous Failures

Finite Slopes
A finite slope is one with a base and top surface, the height being limited. The inclined faces of earth
dams, embankments, excavation and the like are all finite slopes.
Investigation of the stability of finite slopes involves the following steps
a) Assuming a possible slip surface,
b) Studying the equilibrium of the forces acting on this surface, and
c) Repeating the process until the worst slip surface, that is, the one with minimum margin of safety is
found.
Methods:-
I. Total stress analysis for purely cohesive soil.
II. Total stress analysis for cohesive –frictional (c-f) soil – (Swedish method of slices or Method of slices)
III. Effective stress analysis for conditions of steady seepage, rapid drawdown and immediately after construction.
IV. Friction circle method
V. Taylor's method.

5. **B. A new canal is excavated to a 5m below group level through a soil having the characteristics as C=14kN/m^2 , φ=15^o , e=0.8, and G=2.7. The slope of bank is 1:1. If the taylors stability number is 0.083, calculate the factor of safety wrt cohesion when the canal runs full. If it is suddenly emptied, what will be the factor of safety? Take taylors stability number as 0.122.**

Answer:

Solution

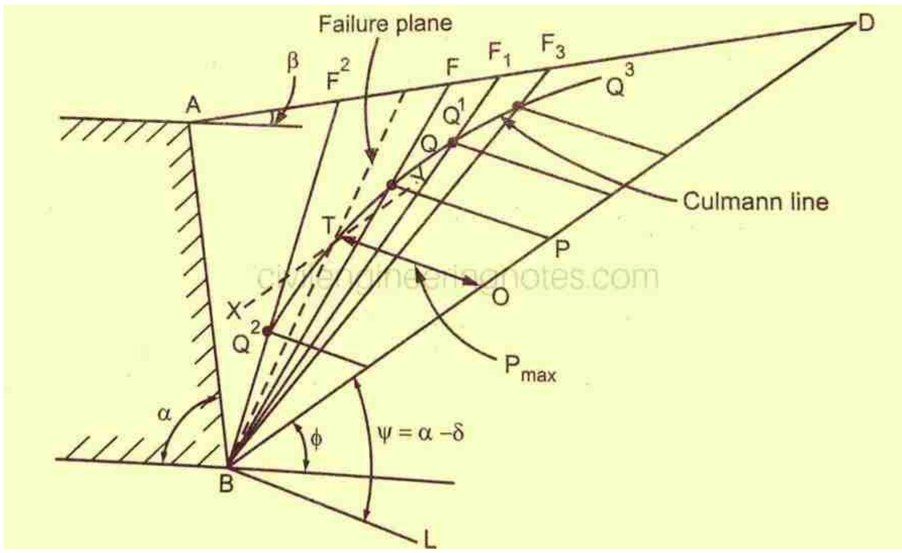
Calculation of Factor of Safety when Canal Runs Full
Given,
Depth of canal, D = 5 m
Slope of banks = 1:1
Cohesion, c = 14 kN/m2
Angle of internal friction, Φ = 15°
Void ratio, e = 0.8
Unit weight of soil, G = 2.70 kN/m3
Effective stress at the bottom of the canal, σ' = γD = 2.70 × 5 = 13.50 kN/m2
The total vertical stress at the bottom of the canal, σv = γD + (1/2)γD = 2.70 × 5.5 = 14.85 k
The horizontal stress at the bottom of the canal, σh = (1/2)σv = 7.43 kN/m2
The effective stress, σ' = σv - σh = 6.42 kN/m2
The shear strength of soil, τ = c + σ'tanΦ = 14 + 6.42 × tan15° = 15.16 kN/m2
The factor of safety with respect to cohesion, FSc = τ/ Sn = 15.16 / 0.083 = 182.17

Calculation of Factor of Safety when Canal is Emptied Suddenly
Given,
Depth of canal, D = 5 m
Slope of banks = 1:1
Cohesion, c = 14 kN/m2
Angle of internal friction, Φ = 15°
Void ratio, e = 0.8
Unit weight of soil, G = 2.70 kN/m3
Effective stress at the bottom of the canal, σ' = γD = 2.70 × 5 = 13.50 kN/m2
The total vertical stress at the bottom of the canal, σv = γD + (1/2)γD = 2.70 × 5.5 = 14.85 k
The horizontal stress at the bottom of the canal, σh = (1/2)σv = 7.43 kN/m2
The effective stress, σ' = σv - σh = 6.42 kN/m2

The shear strength of soil, τ = c + σ'tanΦ = 14 + 6.42 × tan15° = 15.16 kN/m2 The factor of safety with respect to cohesion, FSc = τ/ Sn = 15.16 / 0.122 = 123.93

6. A. Explain the procedure for Culmann's graphical method for active earth pressure.

Answer:



From Coulomb's theory, **Karl Culmann** (1866) devised his own **Culmann's Graphical Method** for calculating earth pressure. According to Coulomb's wedge theory, Culmann's method allows us to graphically calculate the magnitude of the earth pressure and locate the most dangerous rupture surface.

Procedure of Culmann's Method

- To scale, draw the retaining wall **AB**.
- **BD** is the **ϕ-**line.
- A line **BL** is drawn at an angle of 0 with line **BD**, resulting in **Ψ= α – δ**.
- The weight **(W)** of the failure wedge **ABF (γ. ABF)** is calculated using a failure surface **BF** which is totally assumed.
- **BP = W** is obtained by plotting the weight **(W)** along **BD**.
- To intersect the failure surfaces **BF** and **Q**, a line **PQ** is drawn from point **P** parallel to **BL**.
- The magnitude of **Pa** needed to maintain equilibrium for the presumed failure plane is represented by the length **PQ**.
- The process is replicated with several different failure planes **BF_2**, **BF_1**, **BF_3**, etc. As a result, the points **Q^2, Q^1, Q^3** and so on are obtained.
- A smooth curve is drawn joining points **Q^2, Q, Q^1, Q^3** etc. This curve is called Culmann's Line.
- A line **XY** (dotted) tangential to the culmann line and parallel to **BD** is drawn. The point of tangency is designated by the letter **T**.

- Drawing a line **TO** from **T** on **BD** and parallel to **BL** measures the magnitude of largest value of $\mathbf{P_a}$. It's the same as the coulomb's pressure ($\mathbf{P_a}$).
- The failure plane actually passes through point **T (dotted)**.

6. B.

Explain the procedure of Culmann's graphical method for active earth pressure. A retaining wall with a stratified backfill and a surcharge load is shown in the Fig.Q6(b). Draw the earth pressure diagram. Also estimate the resultant thrust on the wall and its position.

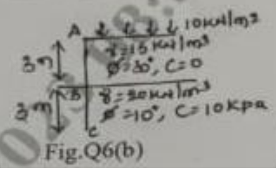


Fig.Q6(b)

(10 Marks)

Answer:

For the second stratum, $Ka_2 = 0.704$

(a) p_a – diagram for top soil

$$pa = (Ka1 \times q) + (ka1 \times \gamma 1 \times z1)$$

$$pa = (0.333 \times 10) + (0.333 \times 15 \times 3) = 18.333 kN/m^2$$

(b) p_a – diagram for bottom soil

$$pa = \left(Ka2 \times (q + (\gamma 1 \times h1))\right) + (ka2 \times \gamma 2 \times z2) - (2 \times c \times \sqrt{ka})$$

or $pa = \left(0.704(10 + (15 \times 3))\right) + (0.704 \times 20 \times z2) - (2 \times 10 \times \sqrt{0.704}) = 21.939 + 14.08z2$

At B, $z2 = 0$; $p_a = 21.939$ kN/m²

At C, $z2 = 3$m; $pa = 21.939 + (14.08 \times 3) = 64.179 \, kN/m^2$

The composite pa diagram is shown in figure – A.

Now $P1 = 3.333 \times 3 = 10 \, kN/m$ Acting at $z_1 = 4.5$ m above base

$P2 = (0.5 \times 15 \times 3) = 22.5 \, kN/m$ Acting at $z_2 = 4.0$ m above base

$P3 = 21.939 \times 3 = 65.817 \, kN/m$ Acting at $z_2 = 1.5$ m above base

$P4 = 0.5 \times 42.24 \times 3 = 63.36 \, kN/m$ Acting at $z_2 = 1.0$ m above base

Total Pa = 10+22.5+65.817+63.36 = 161.677 kN/m Ans.

Acting at $z = \frac{(10\times4.5)+(22.5\times4.0)+(65.817\times1.5)+(63.36\times1.0)}{161.677} = 1.837 \, m \text{ above base.} \quad Ans.$

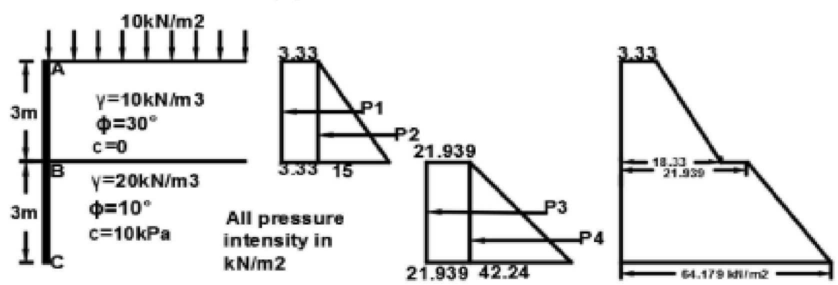


Fig - A

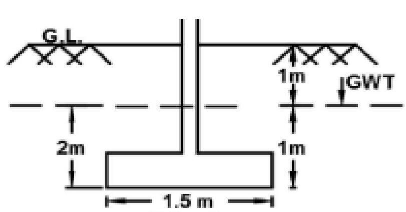


FIG. - B

Sol: 2. For $\emptyset = 0°, Nc = 5.7, Nq = 1.0$ and $N\gamma = 0$

Also Cu = 30kN/m²

Hence $q_f = cN_c + \gamma D \, N_q + 0.5B\gamma N_\gamma = (5.7 \times c) + (\gamma \times D)$

(a) Water table at foundation level

$q_f = (5.7 \times c) + (\gamma_{sat} \times D) = (5.7 \times 30) + (20 \times 2) = 211 kN/m^2$

(b) Water Table at 1m above the foundation level: (see fig – B)

$q_f = (5.7 \times 30) + \left((20 \times 1) + (10.19 \times 1)\right) = 201.19 \, kN/m^2$

% Reduction $= \frac{211-201.19}{211} \times 100 = 4.75\% \, Ans.$

7. A. Explain Standard Penetration test and its corrections.

Answer:

Standard Penetration Test (SPT):

Standard penetration test (SPT) is the most commonly used in situ test for sub- surface investigation. In SPT a split spoon sampler is made to penetrate 15 cm by light blows of a 65 kgs drop hammer on the top of the drill rod. The drill rod is connected to the top of the split spoon sampler.

After initial penetration of 15 cm of the sampler, the drop hammer is allowed to fall from a height of 75cms and number of blows required for 30 cms penetration of sampler is recorded. This number of blows is called N-value or penetration number. In this method the driving energy is supplied by the fail of the drop weight. Hence it is essentially a dynamic sounding method.

Detailed procedure of SPT is as follows:

Apparatus required:

(i) Split spoon sampler:

It has an outside diameter of 50 mm, inside diameter of 35 mm and minimum open length (cutting edge to air vent) of 600 mm. The coupling head has four 10 mm (minimum diameter) vent ports or a ball check value.

(ii) Drive assembly:

It consists of a tripod as hoisting equipment-one of the leg is provided with ladder, a drive mass

(hammer) of 65 kgs, a guide to ensure a 75 cm free fall of the drive mass and an anvil (attached to the guide) for transmitting the blow to the sampler rod.

(iii) Extension rods:

These rods are used to transmit the driving energy from the anvil to the sampler.

(iv) Drilling equipment:

Drilling equipment should be for making a reasonably clear hole of 60-75 mm diameter so as to ensure that the test is performed in undisturbed soil and not in the fall in material. Casing or drilling mud may have to be used where the boring sides fall in.

In general, hand operated auger of 75 mm diameter are used for drilling boreholes.

Procedure:

(1) A borehole is drilled to the required depth and is cleaned thoroughly.

(2) The sampler attached to the extension rods is lowered to the bottom of the hole and is allowed to rest under the self weight. (3) The drive assembly is then connected to the rod and the sampler is driven with light blows from the drive mass to a seating penetration of 15 cm.

(4) The sampler is then driven to an additional penetration of 30 cm by blows from 65 kgs drive mass falling from a height of 75 cm. The number of blows required for 30 cm penetration is recorded as standard penetration resistance, N.

(5) The sampler is then lifted from the hole and opened. The undisturbed sample is removed from the sampler and sealed from both sides.

(6) The test is performed in each identifiable soil layer or at a interval of 1.5 m whichever is smaller. As per IS:2131, for a foundation of width B, penetration test has to be carried out at an interval of 0.75 m up to a depth of B from the bottom of the footing and at 1.5 m interval for the rest depth up to a depth of 1.5 to 2 B.

(7) The measured N-value may indicate more than the actual value in some cases and so they are to be corrected. The standard penetration resistance i.e., N-value has been correlated to different soil properties by different investigators.

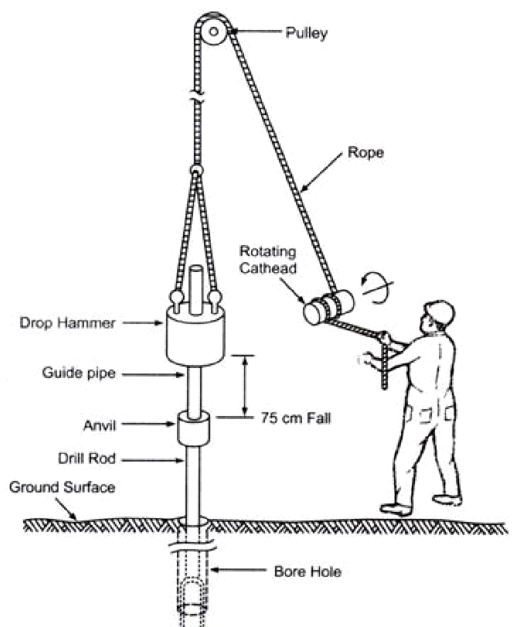


FIG. 10.11 SPT setup

Corrections to Measured Standard Penetration Resistance (N)

It has been observed by different investigators (Tergaghi and peck, 1948; Gibbs and Holtz, 1957; A.W.

Skempton, 1986) that the value of N depends on several factors, such as effective over-burden pressure,

submergence, borehole diameters, rod length etc. Therefore the observed N-value is to be corrected.

The effect of each and corrections are discussed briefly as follows:

Effect of Over-burden:

Gibbs and Holtz (1957) experimentally studied the effect of overburden pressure on the value of N.

Their modification for air dried or moist sand can be represented by the following relation:

$NC = N\ 35/\ \sigma + 7$

Where

Nc = corrected N-value for overburden

N = observed SPT value

σ = effective overburden pressure, t/m2 (not to exceed 28t/m2)

7. B.

b. A strip footing 2m wide carries a load intensity of 400 kN/m² at a depth of 1.2m in sand. The saturated unit weight of sand is 19.5 kN/m³ and unit weight above water table is 16.8 kN/m³. The shear strength parameters are C = 0 and ϕ = 35°. Determine the factor of safety with respect to shear failure for the following cases of location of water table.

i) Water table is 4 m below Ground Level.

ii) Water table is 2.5 m below Ground Level. (10 Marks)

Answer:

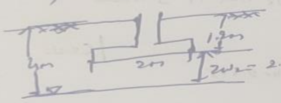
P9) A strip footing 2m wide carries a load intensity of 400 kN/m² at a depth of 1.2m in sand. The saturated unit wt of sand is 19.5 kN/m³ and unit wt above water table is 16.8 kN/m³. The shear strength parameters are C = 0 & φ = 35°. Determine the factor of safety w.r.t shear failure for the following cases of location of water table.

1) W.T is 4m below G.L. [while applying reduction factor for GWT take γ as γ_sat]
2) W.T is 1.2m " "
3) W.T is 2.5m " "
4) W.T is 0.5m " "
5) W.T is at G.L itself

for φ = 35°
$N_q = 41.4$ & $N_\gamma = 42.4$

Soln: Given $q = 400\ kN/m^2$, $\gamma = 16.8\ kN/m^3$ $= \gamma_{bu}$, $C = 0$; $\phi = 35$; $\gamma_{sat} = 19.5\ kN/m^3$

1) W.T is 4m below G.T.



$R_{w_1} = 0.5\left(1+\frac{Z_{w_1}}{D}\right)$ & $\left[R_{w}' = 0.5\left(1+\frac{D_w'}{D_f}\right)\right]$

$= 0.5\left(1+\frac{1.2}{1.2}\right)$ $[Z_{w_1} = D]$

$R_{w_1} = 1$

$Z_{w_2} = 4-1.2 = 2.8m > 2$ ∴ take $R_{w_2} = 1$

[When $Z_{w_2} > B$, the effect of W.T is not considered, & $R_{w_2} = 1$].

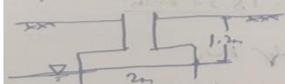
$q_u = CN_c + \gamma D N_q R_{w_1} + 0.5\gamma B N_\gamma R_{w_2}$ | C = 0

$= 0 + 16.8\times1.2\times41.4\times1 + 0.5\times16.8\times2\times42.4\times1$

$q_u = 1546.94\ kN/m^2$

$FOS = \frac{q_u}{q} = \frac{1546.94}{400}$ → $F = 3.86$ ✓

2) When W.T is 1.2m below G.T



$R_{w_1} = 0.5\left[1+\frac{Z_{w_1}}{D}\right]$ $R_{w_2} = 0.5\left(1+\frac{0}{2}\right)$

$R_{w_1} = 0.5\left[1+\frac{1.2}{1.2}\right]$ $R_{w_2} = 0.5$

$R_{w_1} = 1$ & $\gamma = \gamma_{sat}$

$q_u = 0 + \gamma D N_q . R_{w_1} + 0.5\gamma_{sat} B N_\gamma R_{w_2}$

$= 16.8\times1.2\times41.4\times1 + 0.5\times19.5\times2\times42.4\times0.5$

$q_u = 1248.04\ kN/m^2$

$FOS = \frac{1248.04}{400}$ => $FOS = 3.12$ ✓

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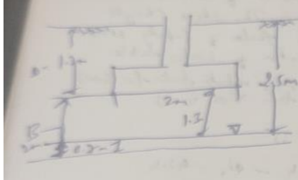
3) When W.T is 2.5m below G.L



$Z_{w_2} = 2.5-1.2 = 1.3m < B$ → $R_{w_1} = 1$

∴ $R_{w_2} = 0.5\left[1+\frac{Z_{w_2}}{B}\right]$

$= 0.5\left[1+\frac{1.3}{2}\right]$

$R_{w_2} = 0.825$

For the surcharge term, take γ_{avg}

$\gamma_{avg} = \frac{1.3\times16.8 + 0.7\times19.5}{(1.3+0.7)}$ → $\gamma_{avg} = 17.745\ kN/m^3$

Use this in 3rd term

$q_u = CN_c + \gamma D N_q R_{w_1} + 0.5\gamma_{avg} N_\gamma R_{w_2}$ | C = 0.

$= 0 + 16.8\times1.2\times41.4\times1 + 0.5\times17.745\times42.4\times0.825$

$q_u = 1455.34\ kN/m^2$

$FOS = \frac{1455.34}{400}$ → $FOS = 3.63$ ✓

8. A. Explain the effect of water table on Bearing capacity of soil.

Answer:

* Effect of Ground Water table on Bearing Capacity:-

The ultimate bearing capacity for shallow footing by the Terzaghi's equa is based on the assumption that the water table is located well below the base of the footing. The bearing capacity gets reduced if the water table rises up comes in contact with the footing.

When the water table is above the base of the footing the submerged wt. γ' should be used for the soil below the water table to compute the over burden Pressure.

When the water table is located some what below the base of the footing the elastic wedge is partly of moist soil and partly of submerged soil i.e the suitable reduction factor should be used in the last term in the bearing capacity equa.

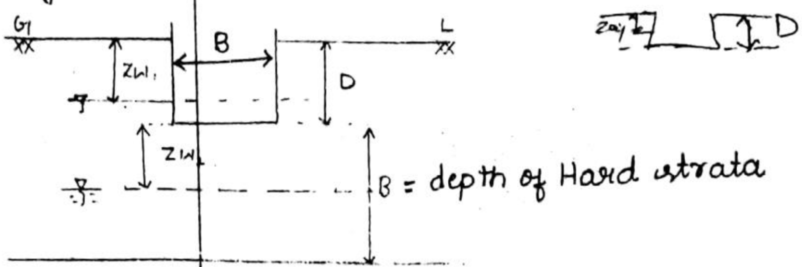
No reduction to be made if the water table is at a depth equal to the width of the footing below base of the footing.

For intermediate positions the linear interpolation of the reduction may be made.

For any position of water table, the bearing capacity equ may be modified as below i.e.

$$q_f = CN_c + \gamma D N_q R_{W_1} + \frac{1}{2}\gamma B N_\gamma R_{W_2}$$

here R_{W_1} & R_{W_2} are the reduction factor for ground water table.



Water table reduction factor R_{W_1} & R_{W_2} can be calculated as follows:-

→ $R_{W_1} = 0.5\left(1 + \frac{Z_{W_1}}{D}\right)$

if $Z_{W_1} = 0$; $R_{W_1} = 1/2$.

if $Z_{W_1} = D$, $R_{W_1} = 1$

→ $R_{W_2} = 0.5\left(1 + \frac{Z_{W_2}}{B}\right)$

if $Z_{W_2} = 0$, $R_{W_2} = \frac{1}{2}$

$Z_{W_2} = B$, $R_{W_2} = 1$

8. B.

b. A square footing 2.5m × 2.5m is built on homogeneous bed of sand of density 19 kN/m³ and having angle of shearing resistance of 36°. The depth of foundation is 1.5m below ground surface. Calculate safe load that can be applied on the footing with factor of safety 3. Take bearing capacity factors as $N_c = 27$, $N_q = 30$ and $N_\gamma = 35$. **(10 Marks)**

Answer:

8.B Soln: Given:

Square footing – 2.5m × 2.5m, $\gamma = 19\ kN/m^3$, $\phi = 36°$, $D_f = 1.5m$

Considering, $N_c = 27$, $N_q = 30$, $N_\gamma = 35$, FOS = 3.

- Ultimate B.C for square footing

$$q_u = 1.3cN_c + \gamma D N_q + 0.4\gamma B N_\gamma \quad | \text{ For sand } c = 0.$$

$$= 19 \times 1.5 \times 30 + 0.4 \times 19 \times 2.5 \times 35$$

$$q_u = 1520\ kN/m^2$$

- Net ultimate BC → $q_{nu} = q_u - \gamma D_f = 1520 - 19 \times 1.5$

$$q_{nu} = 1491.50\ kN/m^2$$

- Safe Bearing Capacity

$$q_s = \frac{q_{nu}}{F} + \gamma D_f = \frac{1491.50}{3} + 19 \times 1.5$$

$$q_s = 525.67\ kN/m^2$$

- Safe load = $q_s \times A$ = $525.67 \times (2.5 \times 2.5)$

$$\text{Safe load} = 3286\ kN$$

9. **A. List the classification piles based on different criteria. Explain the neat sketch classification of piles based on function.**

Answer:

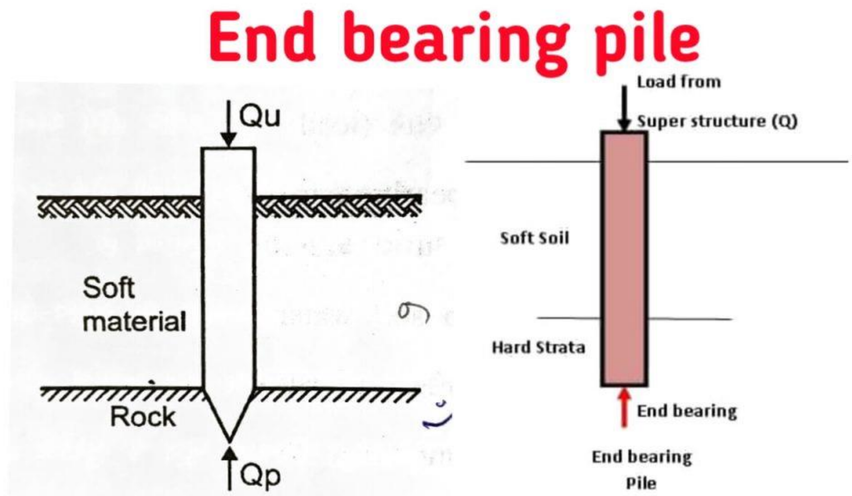
Pile foundation is one type of deep foundation which is used when the bearing capacity of soil is low, in under water construction, load of structure is high, location where shallow foundation is not possible, etc.

Types of pile foundation based on function or use:

1. End bearing pile
2. Friction pile

3. Compaction pile
4. Tension pile
5. Anchor pile
6. Fender pile
7. Better pile
8. Sheet pile

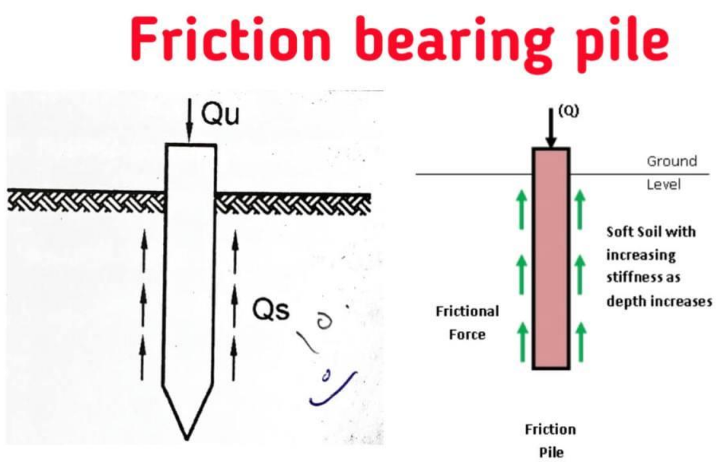
1. End bearing pile:



This type of pile is used to transfer load from water or soft soil to the hard rock below. The load is transferred to the lower end of the pile.

Qu = Qp is used for this pile.

2. Friction pile:



The surface of such pile is kept rough so that the load is carried by the friction (skin friction) generated between the surrounding soil and the surface of the pile.

For a friction pile, Q = Qs

Qu = Ultimate load on pile Qs = Skin friction

The carrying capacity of the friction pile can be increased as follows:

- By increasing the diameter of the pile
- By insert pile to a greater depth.
- By make roughing surface of the pile.
- By keeping group of pile.

9. B.

b. In a 16 pile group, the pile diameter is 45 cm and centre to centre spacing of the square group is 1.5m. If C = 50 kN/m², determine whether the failure would occur with the pile acting individually or as a group? Neglect bearing at the tip of the pile. All piles are 10m long. Take m = 0.7 for shear mobilization around each pile. **(10 Marks)**

Answer:

Pa) A Group of 16 piles of 50cm dia is arranged with a c/c spacing of 1m. The piles are 9m long & are embedded in soft clay having cohesion of 30 kN/m². Bearing resistance may be neglected for the piles. Adhesion factor is 0.6. Determine the ultimate load bearing capacity of the pile group.

Sol: For block failure,

$Q_{ug} = Q_p + Q_s$

$Q_{u(grp)} = C_{ub} N_c \cdot A_b + P_b \times L_b C_u$

Q_p — may be neglected as per question.

$\therefore Q_{u(grp)} = Q_s = P_b \cdot L \cdot C_u$

Given $L = 9m$, $C_u = 30 kpa$ & $B = 3.5m$.

Perimeter of the block $P_b = 4 \times B = 4 \times 3.5$

$P_b = 14m$.

$Q_{u(grp)} = 14 \times 9 \times 30$

$Q_{u(grp)} = 3780 kN$

For piles acting individually,

$Q_{u(sgl)} = n(C N_c A_p + \alpha C A_s)$.

$Q_u = n(\alpha C \cdot A_s)$.

$Q_u = 16(0.6 \times 30 \times \pi \times 0.5 \times 9 \times 16)$.

$Q_{u(in)} = 4071.5 kN$

Here, the foundation is governed by block failure & the ultimate load capacity = 3780 kN

10. Write Short notes on:

a. Efficiency of pile group

b. Negative skin friction

c. Under reamed pile

d. Settlement of pile group

Answer:

a. Efficiency of pile group:

The efficiency of pile group depends on the following factors:

1. Spacing of piles
2. Total number of piles in a row and number of rows in a group, and
3. Characteristics of pile (material, diameter and length)

The reduction in total bearing value of group of piles is more in case of friction piles, particularly in clayey soils. No reduction in grouping occurs in end bearing piles. The pile groups which are resisting the load by combined action of friction and end bearing, only the load carrying capacity of friction is reduced. The efficiency η_g of the pile group can be calculated by using the following formula:

$$\eta_g = \frac{Q_{g(u)}}{NQ_u} \times 100$$

Thus, the pile group efficiency is equal to the ratio of the average load per pile in the group at which the failure occurs to the ultimate load of a comparable single pile. Efficiency of a pile group can also be obtained by using Converse - Labarre formula:

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

Where m = number of rows n = number of piles in a row $\theta = \tan^{-1}\frac{d}{s}$ in degrees d = diameter of pile end s = spacing of piles. Generally center to center spacing between piles in a group is kept between 2.5 d and 3.5d where d is the diameter of the pile.

b. Negative skin friction:

Negative skin friction is usually a downward shear drag acting on a pile or pile group because of downward movement of surrounding soil relative to the piles. This shear drag movements are anticipated to occur when a pile penetrates into compressible soil layer that can consolidate. It is reported that, A small relative movement between the soil and the pile of around 10 mm may be adequate for the full negative skin friction to materialize. Moreover, the time of ending the negative skin fiction of piles is estimated to be around 2 years and the degree of consolidation of the soft soils reaches 90%

c. Under reamed pile

Under reamed piles, also known as bored cast-in-situ piles, are a type of deep foundation used in construction projects to support heavy loads. These piles are created by drilling a hole into the ground and filling it with concrete while simultaneously expanding the bottom section of the hole to form an enlarged bulb-like shape.

This enlarged bulb increases the bearing capacity of the pile and allows it to support heavy loads. Under-reamed piles are commonly used in soft soil conditions where other types of foundations may not be suitable.

d. Settlement of pile group

e. The settlement of a pile or pile group in clay can be computed from the principles of consolidation. Settlement of a pile group is more than the settlement of a single pile, even when the load is the same. This is because the pressure bulb of the pile group is deeper than that of individual piles, causing the compression of a larger volume of soil by the pile group.

f. **For pile groups in sand, the settlement is computed as follows:**

1. As per Skempton:

$$\frac{S_g}{S_i} = \left(\frac{4B+2.7}{B+3.6}\right)^2 \leq 16 \qquad (20.52)$$

2. As per Meyerhof, for a square pile group:

$$\frac{S_g}{S_i} = \frac{S[5-(S/3)]}{[1+(1/r)]^2} \qquad (20.53)$$

Where, S is the ratio of pile spacing to pile diameter and r is the number of rows in a pile group.