Geotechnical & Foundation Engineering

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1A. Define the following terms

1. Plastic Equilibrium

The part of soil is on verge of failure; it is in state of Plastic equilibrium. The stress strain behaviour of the soil is rigid and with idealization of perfectly plastic

2. Angular Distortion

The ~~subject~~ structure is subjected to be angularly distorted if the two foundations support walls/columns.

3. Compressive Index

$$C_c = \frac{\Delta e}{\log_{10}(P_2/P_1)}$$

The compressive index is used to find the settlement in the normally consolidated clay.

where,

Δe is change in void ratio
P_1 is the pressure when void ratio is e_1
P_2 " " " " " " e_2

4. Ultimate Bearing Capacity

It is denoted by 'q_u'. It is the maximum pressure applied on the base of footing that causes shear failure of soil.

5. Poission Ratio of soil

→ Poission ratio represents a change in shape of a material while the volume is maintained constant.

→ In soil terminology, Poission ratio is also known as the co-efficient of lateral expansion and is affected by the following factors

- The soil is a discrete and stratified medium, mostly not elastic and anistropic.
- The soil is not deformed linearly.

B) Problem Statement

Given Data:

cohesion, $C = 0$

angle of internal friction $= \phi = 30^\circ$

unit weight of soil, $\gamma = 19.2\ kN/m^3$

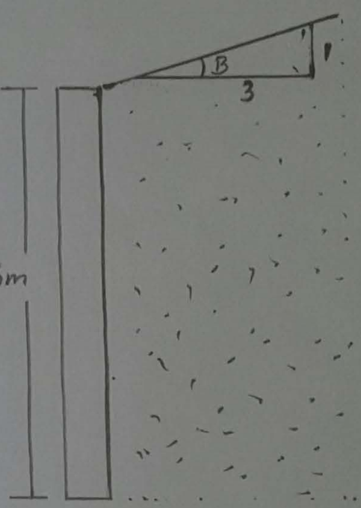
Horizontal slope $= 3$

vertical slope $= 1$

Required

Total Normal force (N_a/b)

Total Shear force (V_a/b)



Sol:-

We know that active force is given by

$$\frac{P_a}{b} = \frac{\gamma \cdot H^2 \cdot k_a}{2}$$

As

$$\tan(B) = \frac{Perp}{Base}$$

$$B = \tan^{-1}(1/3)$$

$$B = 18^\circ$$

Also

Ka is given by

$$k_a = \cos B \times \frac{\cos B - \sqrt{\cos^2 B - \cos^2 \phi}}{\cos B + \sqrt{\cos^2 B - \cos^2 \phi}}$$

$$= \cos(18) \times \frac{\cos(18) - \sqrt{\cos^2(18) - \cos^2(30)}}{\cos(18) + \sqrt{\cos^2(18) - \cos^2(30)}}$$

$$= 0.951 \times \frac{0.951 - \sqrt{0.904 - 0.75}}{0.951 + \sqrt{0.904 - 0.75}}$$

$k_a = 0.395$

Now

By formula

Active force $(P_a/b) = \dfrac{\gamma H^2 \cdot k_a}{2}$

$$= \frac{19.2 \times 6^2 \times 0.395}{2}$$

$$\frac{P_a}{b} = 136.52 \text{ kN/m}$$

~~As the normal for~~

As the Normal force (N_a/b)

$$\frac{N_a}{b} = \frac{P_a}{b} \cdot \cos\beta$$

$$= 136.52 \times \cos\beta$$

$$\frac{N_a}{b} = 129.83 \text{ kN/m}$$

Also the Shear force (V_a/b)

$$\frac{V_a}{b} = \frac{P_a}{b} \cdot \sin\beta$$

$$= 136.52 \times \sin(18)$$

$$\frac{V_a}{b} = 42.18 \text{ kN/m}$$

2A) What is Bearing Capacity? Factors affecting BC

Bearing capacity is the internal strength of soil; and is denoted by 'q'.

Bearing capacity is also known as resistance to load applied.

The pressure which the soil can easily ~~with stand~~ withstand against loads is called "allowing bearing pressure".

Factors affecting Bearing Capacity :

- Type of soil ;
- unit weight (γ) of soil ;
- Surcharge load ;
- Depth of foundation ;
- Size of footing ;
- mode of failure ;
- Shape of footing ;
- Depth of water table ;
- Eccentricity in footing load ;
- Inclination of footing load ;
- Inclination of ground ;
- Inclination of base of foundation

2B) Problem Statement

Given Data:

Footing Dimensions = 2m x 3m (b = 3m, h = 2m)

FoS = 3

Depth of foundation, DF = 1.6m

unit weight of soil, $\gamma = 18 kN/m^3$

Angle of shear resistance, $\phi = 20°$

unit Cohesion, $C_u = 20 kN/m^2$

$N_c = 14.8$

$N_q = 6.4$

$N_\gamma = 2.8$

Required:

Max Safe load, $q_s = ?$

Solution:

According to Meyerhoff's analysis

$$q_u = C \cdot N_c \cdot S_c \cdot d_c + q \cdot N_q \cdot S_q \cdot d_q + \frac{1}{2} \gamma \cdot B \cdot N_\gamma \cdot S_\gamma \cdot d_\gamma$$

→ For shape factors: (S_c, S_q, S_γ)

$$S_c = 1 + 0.2 (B/L) \tan^2 \alpha$$

$$\alpha = 45 + \phi/2$$

$$= 45 + \frac{20}{2}$$

$$\alpha = 55°$$

$$S_c = 1 + 0.2 (2/3) \tan^2 (55)$$

$$\boxed{S_c = 1.27}$$

As $\phi > 10°$

$\therefore$ $S_q = S_\gamma = 1 + 0.1 (B/L) \tan^2 \alpha$

$$= 1 + 0.1 (2/3) \tan^2 (55)$$

$$\boxed{S_q = S_\gamma = 1.135}$$

→ For Depth Factors : (d_c, d_q, d_γ)

$$d_c = 1 + 0.2\left(\frac{D_f}{B}\right)\tan\alpha$$

$$= 1 + 0.2(1.6/2)\tan(55)$$

$$d_c = 1.22$$

~~also $\phi > 10^\circ$~~

Also $\phi > 10^\circ$

∴

$$d_q = d_\gamma = 1 + 0.1(D_f/B)\tan\alpha$$

$$= 1 + 0.1(1.6/2)\tan(55)$$

$$d_q = d_\gamma = 1.11$$

Inclination factors :

For $\theta = 0^\circ$

$$i_c = i_q = i_\gamma = 1$$

By formula

$$q_u = C\,N_c \cdot S_c \cdot d_c + q\,N_q \cdot S_q \cdot d_q + \frac{1}{2}\gamma \cdot B \cdot N_\gamma \cdot S_\gamma \cdot d_\gamma$$

$$= 20 \times 14.8 \times 1.27 \times 1.22 + [1.6 \times 1.8) \times 6.4 \times 1.135 \times 1.11 + \frac{1}{2}(18) \times 2 \times 2.9 \times 1.135 \times 1.11$$

$$q_u = 762 \text{ kN/m}^2$$

As

Net ultimate Bearing Capacity is

$$q_{n.u} = q_u - \bar{\sigma}$$

$$q_{n.u} = 733.2 \text{ kN/m}^2$$

Net safe Bearing Capacity is

$$q_{n.s} = \frac{q_{n.u}}{FOS} = \frac{733.2}{3} = 244.4 \text{ kN/m}^2$$

Safe Bearing Capacity is

$$q_s = q_{n.s} + \bar{\sigma} \Rightarrow 244.4 + (1.6 \times 18)$$

$$q_s = 273.2 \text{ kN/m}^2$$

∴ Safe Bearing Capacity

$$A \times q_s = 273.2 \times 6 m^2$$

$$= 1639.2 kN$$

3A) What is settlement? What are its types

Settlement

Load applied on the ground surface causing stress which leads to vertical strain. This vertical strain causes movement in downward direction. This phenomenon is known as settlement.

Types of settlement

1) Total settlement

Also known as uniform settlement because of the fact that each part of the structure is settled equally. Failure is rare in this case as structure is tend to be rigid. Utility services such as water supply and electricity are avoided & in order to keep the structure firm and sound.

Limitation of uniform settlement

1. The soil should have right bearing capacity to resist the load applied;
2. The load has to cover larger area.

2) Differential Settlement

Here the structure is not uniform as the settlement is done in different parts of structure. It is more dangerous than total or uniform settlements.

Tilt: The entire structure is rotated and leads to unequal settlement.

Angular Distortion: If the two foundation support walls/columns.

3B) Problem Statement

Given Data

Compressive Index of soil $(C_c) = 0.31$
Initial stress/Pressure, $P_1 = 130\ kN/m^2$
Initial void ratio, $e_0 = 1.02$
Final stress/Pressure, $P_2 = 170\ kN/m^2$
Stratum thickness, $H = 5m$

Required:

Final void ratio due to increased stress, $e_1 = ?$
Total (consolidation) Settlement, $S_c = ?$

Sol:-

As compressive Index is given by,

$$C_c = \frac{\Delta e}{\log_{10}\left(\frac{P_2}{P_1}\right)} = \frac{e_0 - e_1}{\log_{10}\left(\frac{P_2}{P_1}\right)}$$

$$0.31 = \frac{1.02 - e_1}{\log_{10}\left(\frac{170}{130}\right)} \Rightarrow 0.31 \times 0.1165 = 1.02 - e_1$$

$$e_1 = 0.984$$

By Formula

Consolidation Settlement is,

$$S_c = \frac{H}{1 + e_0} \times C_c (\log_{10})\left(\frac{P_2}{P_1}\right)$$

$$= \frac{5}{1 + 1.02} \times 0.31 \times \log_{10}\left(\frac{170}{130}\right)$$

$$= 0.0893m$$

$$S_c = 89.3\ mm$$