GEOTECHNICAL & FOUNDATION ENGINEERING

Geology → The branch of Science which deals about
- History of Earth
- Structure of Earth
- The materials from which the earth is composed.

Geodesy → The branch of Science which deals about
- Shape of the earth
- Size of the earth
- Position of the earth

Geography → The branch of Science which deals about the features of the earth and its atmosphere and also the human activity which affect it.

Geomorphology → The branch of Science in which we deal about the external structure of the earth in relationship with other geological structure (moon).

Geotechnical Engineering:-

The branch of civil Engineering in which we deals about rock, soil and ground water table and relation of these with design, construction and operation of of civil engineering projects.

Civil Engineering projects include Road, Bridge, Building, Dam etc.

Issues of Geotechnical Engineering :-

→ To study the sub-surface rock and soil of the construction site.

→ To study the effect of ground water table in the present as well as in the future on the soil. What will be the effect of ground water table on the foundation of a structure.

→ If a civil Engineering project require a retaining wall then the type of and its designed is decided by the Geotechnical Engineering.

→ Proposed slope and natural slope are stabilized by a Geotechnical Engineer.

→ If a civil Engineering project requires a Tunnel then how to excavate, how to support it is performed by a Geotechnical Engineer.

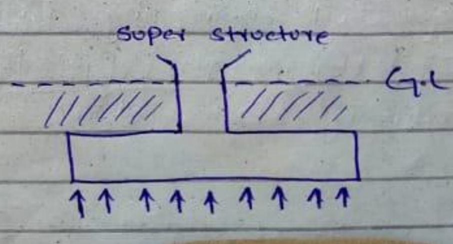
Chapter # 02

⇒ Bearing Capacity :-

- An Engineering Property of soil because of which when load is applied on the ground surface and this load is resisted then such capacity of soil is called Bearing Capacity.
- It is also called the internal strength of the soil. Denoted by "q".

⇒ Gross Pressure :-

The max. pressure at the base of footing due to:-



- Self weight of footing
- overburden pressure
- Load of super structure

Overburden pressure is due to the soil portion over the footing.

Overburden pressure is denoted by ($\bar{\sigma}$).

$$\bar{\sigma} = D \times \gamma_s$$

D = Depth of Foundation

γ_s = Unit weight of soil

⇒ **Net Pressure :-**

The part of Gross Pressure which have no overburden Pressure.

OR

The pressure at the base of footing due to

- Self weight of the footing.
- Load of the superstructure

⇒ **Ultimate Bearing Capacity / Pressure :-**

Denoted by "q_u".

The max. pressure at the base of the footing which cause shear failure in the soil.

⇒ **Net Ultimate Bearing Capacity / Pressure :-**

Denoted by "q_{nu}"

When the overburden pressure is removed from the U.B.C then the remaining pressure is called Net Ultimate Bearing Capacity.

⇒ **Net Safe Bearing Capacity / Pressure :-**

It is obtained by dividing the "q_{nu}" on Factor of Safety.

$$q_{ns} = \frac{q_{n.u}}{F.O.S}$$

⇒ **Safe Bearing Capacity / Pressure :-**

It is obtained by adding the net safe bearing pressure to overburden pressure.

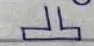
$$q_s = q_{n.s} + \bar{\sigma}$$

Lecture # 2

Terzaghi's Bearing Capacity Theory :-

Assumptions :-

→ The soil is homogenous and having shear parameter C and ϕ.
(C = Cohesion , ϕ = Angle of Internal friction)

→ The footing is continous strip footing. 

→ The load is concentrated and vertical.

→ The analysis is two dimensional.

→ The mode of failure will be General shear failure.

→ The ground surface is horizontal.

→ The depth of the footing is at shallow depth.

For Strip Footing :-

$$q_u = C N_c + q N_q + 0.5\, \gamma \cdot B \cdot N_\gamma$$

where

q_u = Ultimate Bearing Capacity

C = Cohesion

q = Surcharge $\because (q = D_s \times \gamma_s)$ (D_s → Depth of footing)

B = Bredth of the footing

γ = Unit weight of the soil

N_c, N_q, N_γ are called Terzaghi's Bearing Capacity factor.

For Square Footing :-

$q_u = 1.2\, C N_c + q N_q + 0.4\, \gamma \cdot B \cdot N_\gamma$

For Circular Footing :-

$q_u = 1.2\, C N_c + q N_q + 0.3\, \gamma \cdot B \cdot N_\gamma$

=> If $\phi > 36°$, then all of the above formulae are valid and the failure will be General shear Failure.

=> If $\phi < 29°$, then the failure will be local shear failure and the above formula's will be modified :

$C \rightarrow C_m$, $\phi \rightarrow \phi_m$

=> $C_m = 2/3\, C$ => $\tan \phi_m = \frac{2}{3} \tan \phi$

$\phi_m = \tan^{-1}\left(\frac{2}{3} \tan \phi\right)$

=> If $29° \leq \phi < 36°$, then it will punching shear failure.

$N_q = \tan^2\left(45 + \frac{\phi}{2}\right) \cot \phi$

$N_c = (N_q - 1) \cot \phi$

$\cot \phi = \frac{1}{\tan \phi}$

Problem # 01

A Square footing 2m x 2m is built in a homogenous bed of sand of density 1.9 t/m³ and having an angle of shearing resistance of 38°. The depth of the base of footing is 0.8m below the ground surface. What is the safe bed according to the Terzaghi's analysis which can be ~~called~~ carried by the footing with a factor of safety 3 against complete shear failure ?

The

Problem # 02

The footing of a wall is 1.5m wide at the base and is located in a homogenous Cohesive soil at the depth of 1m below the ground surface.

The soil properties are $\gamma = 1.76\ \text{ton/m}^3$, $\phi = 20°$

$c = 3.6\ \text{ton/m}^2$

Assuming the soil as soft which is likely to fail by local shear, determine the safe bearing capacity per meter length of footing.

Given Data :-

Width of footing wall = 1.5m

Depth of foundation = 1m

Unit weight of soil (γ) = $1.76\ t/m^3$

Internal angle of friction (ϕ) = $20°$

Cohesion (c) = $3.6\ \text{ton/m}^2$

F.o.S = 3

$N_c = 4$

$N_q = 1.1$

$N_\gamma = 1.6$

Required :-

Safe Bearing Capacity (q_s) = ?

Given Data:-

Unit weight of soil $= (\gamma) = 1.9\ t/m^3$

Internal angle of friction $(\phi) = 38°$

Depth of base footing $(D_f) = 0.8m$

Factor of Safety $= 3$

Required :-

Safe Bearing Capacity $(q_s) = ?$

Sol:

According to Terzaghi's Analysis

$q_u = 1.2\, c N_c + q N_q + 0.4\, \gamma \cdot B \cdot N_\gamma$

$q = D_f \times \gamma_s$

$= 0.8 \times 1.9 \quad \Rightarrow \quad q = 1.52\ t/m^2$

For sand, $c = 0$

$q_u = 1.2\, c N_c + q N_q + 0.4\, \gamma \cdot B \cdot N_\gamma$

$= 1.2(0) N_c + (1.52)(61.51) + 0.4\,(1.9)(2)(82.3)$

$= 0 + 93.49 + 125.096$

$q_u = 218.586\ t/m^2$

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

$q_{n.u} = 218.586 - 1.52$

$= 217.07\ t/m^2$

As, $q_{n.s} = \dfrac{q_{n.u}}{F.o.S} = \dfrac{217.07}{3}$

$q_{n.s} = 72.35\ ton/m^2$

Sol:-

According to Terzaghi's Analysis for strip footing,

$q_u = C_m N_c + \gamma D_f \cdot N_q + 0.5 \cdot \gamma \cdot B \cdot N_\gamma$

=> $C_m = 2/3\, c$

$= 2/3 \times 3.6 = 2.4\ t/m^2$

=> $\phi_m = \tan^{-1}(2/3 \tan \phi)$

$= \tan^{-1}(2/3 \tan(20)^\circ) = 13.64^\circ$

=> $q_u = (2.4)(4) + (1.76 \times 1 \times 1.1) + 0.5(1.76 \times 1.5 \times 1.6)$

$q_u = 13.64\ ton/m^2$

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

$= 13.64 - (1.76 \times 1)$

$q_{n.u} = 11.88\ t/m^2$

=> $q_{n.s} = \frac{q_{n.u}}{F.o.s} = \frac{11.88}{3} = 3.96\ t/m^2$

=> $q_s = q_{n.s} + \bar{\sigma}$

$= 3.96 + (1.76 \times 1)$

$\boxed{q_s = 5.72\ ton/m^2}$

If along the length of footing, then

$= 5.72 \times 1.5$

$q_s = 8.58\ ton/m$

Geotechnical and Foundation Engineering

Factors Affecting Bearing Capacity :-

=> Relative density of the soil :-

Greater the Relative Density of soil, higher will be the value of angle of internal friction (ϕ) and higher will be Terzaghi bearing capacity factors (N_c, N_q, N_γ) due to which the value of Bearing capacity will increase.

- Depth of the footing :-

As, $q_u = cN_c + \gamma D_f N_q + \frac{1}{2} \gamma \cdot B \cdot N_\gamma$

So $q_u \propto D_f$

Soil type → dense ↓ will increase the q_u.

=> The bearing capacity increase with increase of depth of the footing. This increase is maximum for the dense soil as compared to loose sand.

=> Width of the footing :-

The bearing capacity increase with the increase of width of the footing this will increase will be max. for the dense soil as compared to loose sand.

=> Unit weight of the soil :-

$$q_u = cN_c + (\gamma) D_f N_q + \frac{1}{2} \gamma \cdot B \cdot N_\gamma$$

Increase in "γ" will increase in q_u.

=> Cohesion of the soil :-

=> Water Table :-

It has indirect relation with the bearing capacity. Due to water, the shear strength b/w the soil particles reduces hence q_u decreases.

Mayerhof's Bearing Capacity Equation :-

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

where,

q_u = Ultimate bearing capacity

C = Cohesion

$S_c, S_q, S_\gamma \rightarrow$ shape factors

$d_c, d_q, d_\gamma \rightarrow$ Depth factors

$i_c, i_q, i_\gamma \rightarrow$ Inclination factor

N_c, N_q, N_γ
↓
will be given in table.

$N_c = (N_q - 1) \cot\phi$

$N_q = (e^{\pi \cdot \tan\phi}) \tan^2(45 + \frac{\phi}{2})$

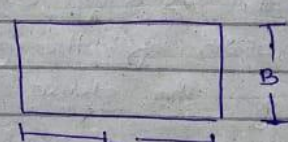
N_γ = ~~$(N_q - 1) \tan(1.4\phi)$~~
$2(N_q + 1)\tan\phi$

Shape Factors :-

Shape factor due to Cohesion → S_c

$S_c = 1 + 0.2 \frac{B}{L} \tan^2\alpha$

$\alpha = (45 + \frac{\phi}{2})$



ϕ = angle of internal friction

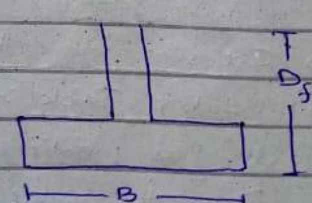
$S_q = S_\gamma = 1 \rightarrow, \phi = 0^\circ$

$S_q = S_\gamma = 1 + 0.1 \frac{B}{L} \tan^2\alpha \rightarrow \phi \geq 10^\circ$

Depth Factors :-

$d_c = 1 + 0.2 \frac{D}{B} \tan\alpha$

$\alpha = 45 + \frac{\phi}{2}$



$\phi = 0^\circ \rightarrow d_q = d_\gamma = 1$

$\phi > 10^\circ \rightarrow d_q = d_\gamma = 1 + 0.1 \frac{D}{B} \tan\alpha$

Inclination Factors:-

$i_c = i_q = \left(1 - \frac{\theta}{90}\right)^2$

$i_\gamma = \left[1 - \frac{\theta}{\phi}\right]^2$

$\phi = 0^\circ \rightarrow \quad i_c = i_q = i_\gamma = 1.$

Problem #3

What is the maximum safe load which can be supported by a rectangular footing 2m × 3m with FOS 3. The base of the footing at 1.6m below ground level. Unit weight of soil is 18 kN/m³, angle of shear resistance $\phi = 20^\circ$, unit cohesion "c" = 20 kN/m². Use Mayerhof's Analysis.

Given data :-