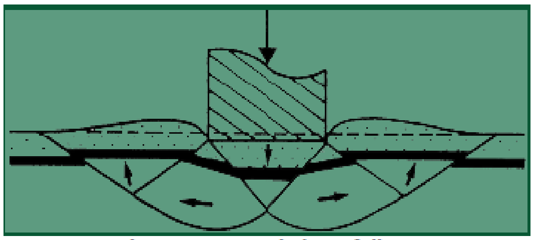
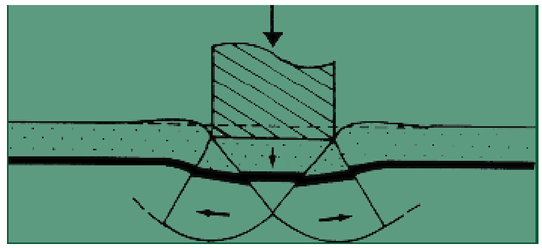
<u>**Internal Assessment Test 2 Solutions – April 2017**</u>

<u>**Geotechnical Engineering-II**</u>

**Q1.(a) Distinguish general shear failure from local shear failure.**
***Ans:-***

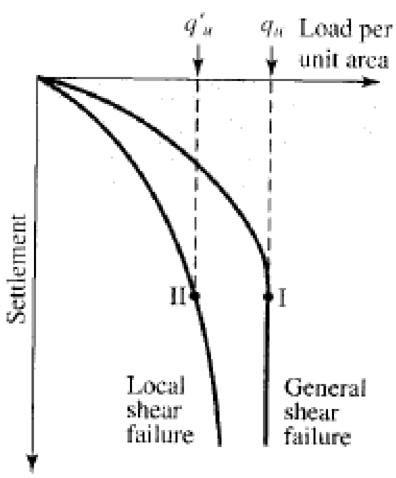


*General shear failure*



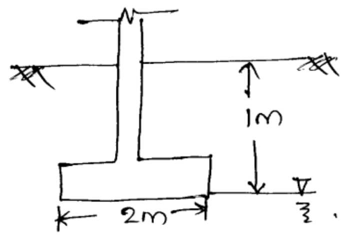
*Local shear failure*

| **General Shear Failure** | **Local/Punching Shear Failure** |
|---|---|
| Occurs in dense/stiff soil<br>$\Phi>36^{\circ}$, N>30, $I_D>70\%$, $C_u>100$ kPa | Occurs in loose/soft soil<br>$\Phi<28^{\circ}$, N<5, $I_D<20\%$, $C_u<50$ kPa |
| Results in small strain (<5%) | Results in large strain (>20%) |
| Failure pattern well defined & clear | Failure pattern not well defined |
| Well defined peak in P-Δ curve. | No peak in P-Δ curve |
| Bulging formed in the neighbourhood of footing at the surface | No Bulging observed in the neighbourhood of footing |
| Extent of horizontal spread of disturbance at the surface large | Extent of horizontal spread of disturbance at the surface very small |
| Observed in shallow foundations | Observed in deep foundations |




**Q1(b). A strip footing 2m wide is placed at a depth of 1 m below the GL. Determine the safe \bearing capacity, given the following data. C = 30 kPa, $\Phi$= 25$^{o}$, $\gamma_{sat}$ = 19 kN/m$^3$, Nc = 11.8, Nq = 3.9, $N_{\gamma}$ = 1.7 and F = 3. Assume water table is at the base of footing.**
***Ans:-***

Ans:- $B = 2m$, $D_f = 1m$, $C = 30\ kN/m^2$, $\gamma_{sat} = 19\ kN/m^3$, $N_c = 11.8$, $N_q = 3.9$, $N_\gamma = 1.7$, $F = 3.0$




$C_m = \frac{2}{3} \times 30 = \underline{20\ kN/m^2}$

$q_u = cN_c + 0.5B\gamma_{sub}N_\gamma W_\gamma + \gamma_{sat}D_f N_q W_q$.

$W_\gamma = \frac{1}{2}\left[1 + \frac{0}{2}\right] = 0.5$.

$W_q = \frac{1}{2}\left[1 + \frac{1}{1}\right] = 1.0$.

$\gamma_{sub} = \gamma_{sat} - \gamma_w = 19 - 10 = \underline{9\ kN/m^3}$

$q_u = (20 \times 11.8) + (0.5 \times 2 \times 9 \times 1.7 \times 0.5) + (19 \times 1 \times 3.9 \times 1.0)$
$= \underline{317.75\ kN/m^2}$

$q_{nu} = q_u - \gamma_{sat}D_f$
$= 317.75 - (19 \times 1) = \underline{298.75\ kN/m^2}$

$q_{ns} = \frac{q_{nu}}{F} = \frac{298.75}{3.0} = \underline{99.58\ kN/m^2}$

$q_s = q_{ns} + \gamma_{sat}D_f = 99.58 + (19 \times 1)$
$= \underline{118.58\ kN/m^2}$

**Q2.(a) A 7 m deep canal has side slope of 1:1. The properties of the soil are C = 15 kN/m$^2$, Φ = 20°, e = 0.65 & G = 2.6. If $S_n$ = 0.05, determine the FOS wrt cohesion when the canal runs full. Also find the same in case of sudden draw down, if Taylor's stability no: for this condition is 0.097.**

***Ans:-***

$H = 7m$, $C = 15\ kN/m^2$, $e = 0.65$, $G = 2.6$, $S_n = 0.05$.

$\gamma_{sat} = \frac{(G+e)\gamma_w}{1+e} = \frac{(2.6+0.65)10}{(1+0.65)}$
$= \underline{19.69\ kN/m^3}$

$\gamma_{sub} = \gamma_{sat} - \gamma_w = 19.69 - 10 = \underline{9.69\ kN/m^3}$

<u>When canal runs full:-</u> $\gamma = \gamma_{sub}$.

$S_n = \frac{C}{F_c \times \gamma_{sub} \times H} \Rightarrow F_c = \frac{C}{S_n \times \gamma_{sub} \times H}$

$= \frac{15}{0.05 \times 9.69 \times 7} = \underline{4.42}$

During sudden draw down :– $\gamma = \gamma_{sat}$

$$F_c = \frac{15}{0.097 \times 19.69 \times 7} = \underline{\underline{1.12}}$$

**Q2.(b) Write brief critical notes on Taylor's stability number.**

***Ans:-*** In a slope the component of the self weight (g) causes instability and the cohesion contributes to stability. The maximum height (Hc) of a slope is directly proportional to unit cohesion (Cu) and inversely proportional to unit weight (g). In addition, Hc is also related to friction angle (fu) and slope angle b.

This can be expressed as
$$H_c = \frac{C_u}{\gamma} f(\phi_u, \beta)$$

When the term f( $\Phi_u$, β) is dimensionless then equation above is dimensionally balanced. Taylor (1937) expressed f( $\Phi_u$, β) as a reciprocal of a dimensionless number called "Stability Number" (Sn) popularly called as Taylor's stability Number.

$$f(\phi_u, \beta) = \frac{1}{S_n}$$

$$\therefore H_c = \frac{C_u}{\gamma S_n}$$

$$S_n = \frac{C_u}{\gamma H_c}$$

**Q3.(a) Explain the components of settlement and their determination.**

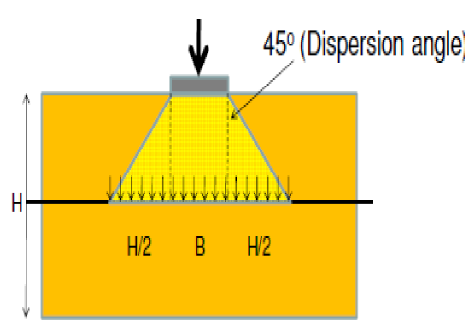
***Ans:-*** **<u>Consolidation Settlement</u>**:-

- It occurs due to the process of consolidation.
- Clay and Organic soil are most prone to consolidation settlement.
- It is a time related process occurring in saturated soil by draining water from void.
- Spring analogy explains consolidation settlement.

Consolidation Settlement in normally consolidated clayey soil is given by the expression,

$$S_c = \left(\frac{C_c}{1+e_o}\right) H \log_{10}\left(\frac{\sigma_o + \Delta\sigma}{\sigma_o}\right)$$

$S_c$ = Consolidation Settlement
$C_c$ = Compression Index
$e_o$ = Initial Void Ratio
H = Thickness of clay layer
$\sigma_o$ = Initial overburden pressure at the middle of clay layer
$\Delta\sigma$ = Extra pressure due to the new construction



$$\sigma_o = \gamma_{sat}\frac{H}{2}$$

$$\Delta\sigma = \frac{P}{\left(2\frac{H}{2}+B\right)^2}$$

**Secondary Settlement**:- This settlement starts after the primary consolidation is completely over. During this settlement, excess pore water pressure is zero. This is creep settlement occurring due to the readjustment of particles to
a stable equilibrium under sustained loading over a long time.
5. This settlement is common in very sensitive clay, organic soils and loose
sand with clay binders.

$$S_S = C_\alpha H \log_{10}\left[\frac{t_{sec}-t_{prim}}{t_{prim}}\right]$$

$C_\alpha$ = Coefficient of secondary compression
H = Thickness of clay layer
$t_{sec}$ = Time taken for secondary compression (usually life span of structure)
$t_{prim}$ = Time taken for primary consolidation to complete (EPWP to become zero)

**Immediate settlement**:- Immediate settlement is also called elastic settlement.
• It is determined from elastic theory.
• It occurs in all types of soil due to elastic compression.
• It occurs immediately after the application of load.
• It depends on the elastic properties of foundation soil, rigidity, size and shape of foundation.
Immediate settlement is calculated by the equation mentioned below.

$$S_I = \left(\frac{1-\mu^2}{E}\right)qBI_\rho$$

Here,

$S_i$= Immediate settlement, μ = Poisson's Ratio of foundation soil
E = Young's modulus of Foundation Soil, q = Contact pressure at the base of foundation
B = Width of foundation, I = Influence Factor

**Q3.(b) Determine the immediate settlement of a footing 3m*3m, resting on sandy soil with Es=45000kPa, μ=0.3, I =0.82. Footing carries a load of 2000 kN.**

***Ans:-***

Given:- $A = 3m \times 3m$, $E_s = 45{,}000\ KN/m^2$, $\mu = 0.3$, $I = 0.82$,

Load = 2000 KN

$$q = \frac{\text{Load}}{\text{area}} = \frac{2000}{3\times 3} = 222.22\ KN/m^2$$

$$S_i = \left(\frac{1-\mu^2}{E_s}\right) \times q \times B \times I$$

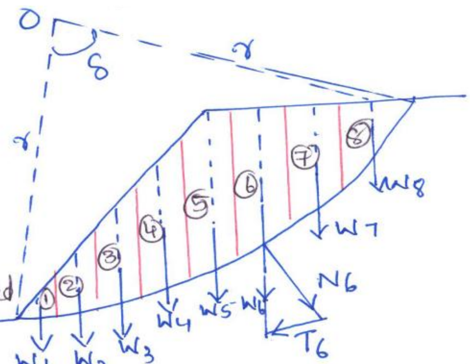
$$= \left(\frac{1-0.3^2}{45,000}\right) \times 222.22 \times 3 \times 0.82$$

$$= 0.011\,m = \underline{11.05\,mm}$$

**Q4.(a) Explain the Swedish Circle method of stability analysis for a C-Φ soil.**

***Ans:-***

(2) $c-\phi$ analysis




→ Trial $\bigcirc^{le}$ is drawn, & material above slip circle is divided into a convenient no. of vertical slips or slices.

→ The forces b/w the slices are neglected.

→ Each slice is assumed to act independently as a column of soil of unit thickness & width b.

→ Weight 'W' of each slice can be resolved into normal 'N' & tangential 'T' components.

'N' passes through centre of rotation 'O' & hence do not cause any driving moment on the slice.

$N = W\cos i$ & $T = W\sin i$.

Driving moment, $M_D = T \times r = W\sin i \times r$
$= r \times \Sigma T$.

Resisting moment, $M_R = r\left[C\,\Sigma\Delta L + \Sigma N\tan\phi\right]$

where $\Sigma\Delta L = \hat{L} = \frac{2\pi r\delta}{360°}$ = length AB of slip $\bigcirc^{le}$.

$\therefore$ $\boxed{\text{FOS against sliding} = \frac{C\hat{L} + \Sigma N\tan\phi}{\Sigma T}}$

A no. of trial $\bigcirc^{les}$ are chosen & FOS in each case is computed. $\bigcirc^{le}$ giving min FOS is the critical slip circle.

**Q4.(b). Define: 1) Ultimate bearing capacity 2) Net ultimate bearing capacity 3) Safe bearing capacity 4) Allowable bearing pressure.**

***Ans:-* Ultimate Bearing Capacity ($q_u$)** : It is the maximum pressure that a foundation soil can withstand without undergoing shear failure.

**Net ultimate Bearing Capacity ($q_{nu}$) :** It is the maximum extra pressure (in addition to initial overburden pressure) that a foundation soil can withstand without undergoing shear failure.

$$q_{nu} = q_u - \gamma D$$

Here, $\gamma$ D represents the overburden pressure at foundation level where $\gamma$ is the unit weight of soil and D is the depth to foundation bottom from Ground Level.

**Safe Bearing Capacity (qs) :** It is the safe extra load the foundation soil is subjected to in addition to initial overburden pressure.

$$q_s = q_{ns} /F + \gamma D$$

Here F represents the factor of safety.

**Allowable Bearing Pressure (qa) :** It is the maximum pressure the foundation soil is subjected to considering both shear failure and settlement.

**Q5.(a). Explain any four limitations of plate load test.**

***Ans:-***The plate load test has the following limitations:

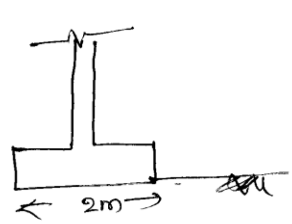
1) Size effect:- The test does not truly represent the actual conditions if the soil is not homogeneous and isotropic to a large depth.
2) Scale effect:- The ultimate bearing capacity of saturated clays is independent of the size of the plate but for cohesionless soils, it increases with the size of the plate.
3) Time effect:- For clayey soils the test does not give the ultimate settlement since it is of short duration.
4) Reaction load:- It is not practical to provide a load more than 250 kN. Hence test on a plate of size larger than 0.6 m width is difficult.
5) Water table:- If the water table is above the level of the footing, it has to be lowered by pumping before placing the plate.

**Q5.(b). Calculate the ultimate BC of a 2m wide square footing in a sand deposit 1) resting on ground surface 2) when it is placed 1m below ground level. The foundation soil has the following properties: $\gamma$ = 18.6 kN/m$^3$, $\Phi$= 38$^o$. Also calculate the % increase in BC with increase in depth from surface to 1m below GL. $N_\gamma$ = 41.4, Nq = 42.**

***Ans:-***

Given :- $B = 2m$, $c = 0$, $N_\gamma = 41.4$, $N_q = 42$, $\gamma = 18.6\ kN/m^3$.

Case I :- $D_f = 0$.




$$q_u = 0.4 B \gamma N_\gamma + 0$$

$$= 0.4 \times 2 \times 18.6 \times 41.4 = 616.032\ kN/m^2$$

Case II $D_f = 1m$.

$q_u = 0.4 B \gamma N_\gamma + \gamma D_f N_q$

$= 616.032 + 18.6 \times 1 \times 42 = \underline{1397.232}\ kN/m^2$

% increase in bearing capacity $= \dfrac{1397.232 - 616.032}{616.032}$

$= \underline{\underline{126.81\%}}$

**Q6.(a). List the assumptions of Terzaghi's bearing capacity equation.**

***Ans:-***

1. The base of the footing is rough.
2. The footing is laid at a shallow depth i.e. $D_f \leq B$.
3. The shear strength of the soil above the base of the footing is neglected. The soil above the base is replaced by a uniform surcharge $\gamma D_f$.
4. The load on the footing is vertical & is uniformly distributed.
5. The footing is long i.e. L/B ratio is infinite where B is the width and L is the length of the footing.
6. The shear strength of the soil is governed by the Mohr-Coulomb eqn.
7. Soil is homogeneous & isotropic.
8. Elastic zone has straight boundaries inclined at an angle equal to $\Phi$ to the horizontal.

**Q6.(b) The soft normally consolidated clay layer is 18 m thick with following properties: LL= 63 %, $\gamma_{sat}$ = 18 kN/m$^3$, w= 28 % and G = 2.70. The vertical stress increment at the center of the layer is 9 kN/m$^2$. The ground water level is at surface of clay layer. Determine consolidation settlement.**

***Ans:-***

<u>Given</u> :- $H = 18\,m$, $LL = 63\%$, $\gamma_{sat} = 18\,KN/m^3$, $w = 28\%$, $G = 2.70$.

$\Delta\sigma = 9\,KN/m^2$

$$S_c = \frac{C_c}{1+e_0} \times H \times \log_{10}\left(\frac{\sigma_0 + \Delta\sigma}{\sigma_0}\right)$$

$$\sigma_0 = \gamma_{sub} \times \frac{H}{2} = (18-10) \times \frac{18}{2} = 72\,KN/m^2$$

$$C_c = 0.009(63-10) = 0.477$$

$$e_0 = w \times G = 0.28 \times 2.70 = 0.756$$

$$\therefore S_c = \frac{0.477}{1+0.756} \times 18 \times \log_{10}\left(\frac{72+9}{72}\right)$$

$$= 0.250\,m = \underline{\underline{250.111\,mm}}$$