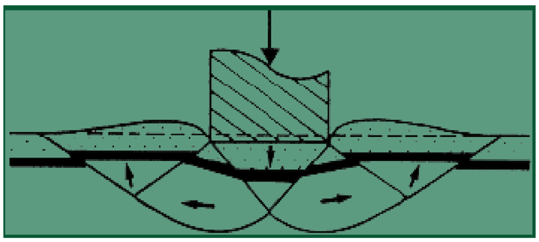
SOLUTION IAT2

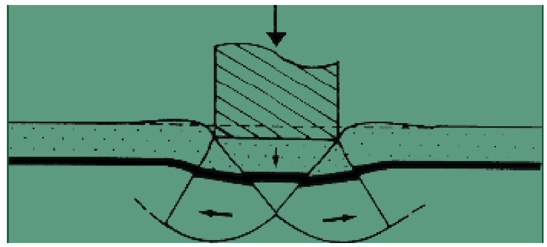
GEOTECHNICAL ENGINEERING-II (10CV64)

1(a).Distinguish general shear failure from local shear failure.

Ans:-

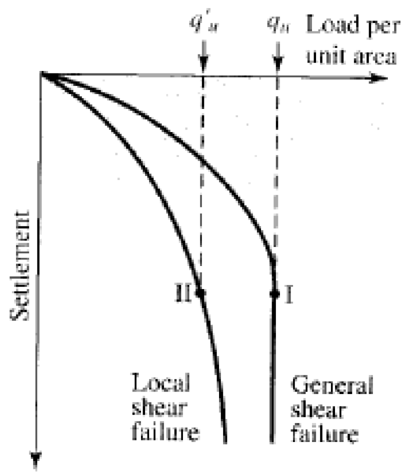


General shear failure



Local shear failure

General Shear Failure	Local/Punching Shear Failure
Occurs in dense/stiff soil $\Phi>36^{\circ}$, $N>30$, $I_D>70\%$, $C_u>100$ kPa	Occurs in loose/soft soil $\Phi<28^{\circ}$, $N<5$, $I_D<20\%$, $C_u<50$ 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



1(b).Briefly explain the effect of WT on bearing capacity.

Ans:-

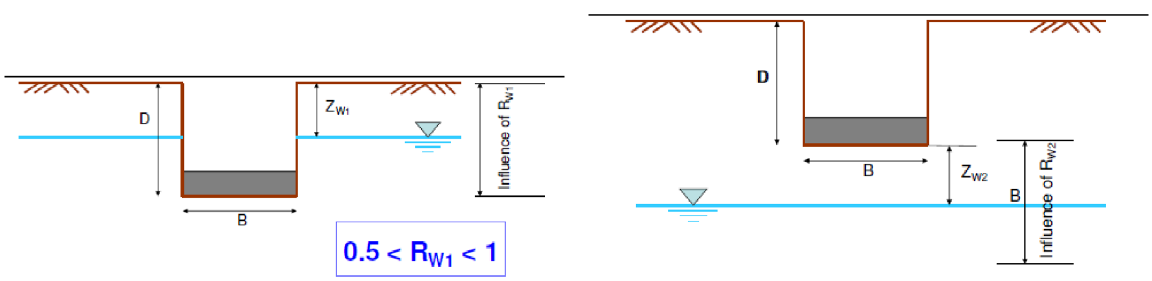


Fig. 7.5 : Effect of water table on bearing capacity

Ultimate bearing capacity with the effect of water table is given by,

$$q_f = cN_c + \gamma D N_q R_{w1} + 0.5\gamma B N_\gamma R_{w2}$$

Here, $R_{w1} = \frac{1}{2}\left[1 + \frac{Z_{w1}}{D}\right]$

where Z_{W1} is the depth of water table from ground level.

1. $0.5 < R_{w1} < 1$
2. When water table is at the ground level ($Z_{w1} = 0$), $R_{w1} = 0.5$
3. When water table is at the base of foundation ($Z_{w1} = D$), $R_{w1} = 1$
4. At any other intermediate level, R_{w1} lies between 0.5 and 1

Here, $R_{w2} = \frac{1}{2}\left[1 + \frac{Z_{w2}}{B}\right]$

where Z_{W2} is the depth of water table from foundation level.

1. $0.5 < R_{w2} < 1$
2. When water table is at the base of foundation ($Z_{w2} = 0$), $R_{w2} = 0.5$
3. When water table is at a depth B and beyond from the base of foundation ($Z_{w2} >= B$), $R_{w2} = 1$
4. At any other intermediate level, R_{w2} lies between 0.5 and 1

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

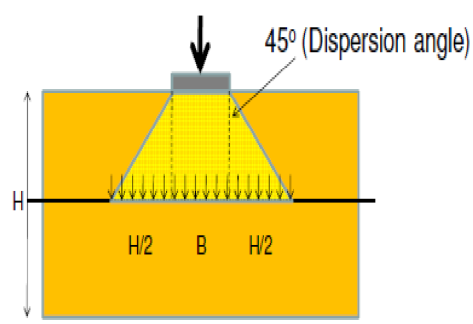
Ans:- Consolidation Settlement:-

- 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
σ_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_α = 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.

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

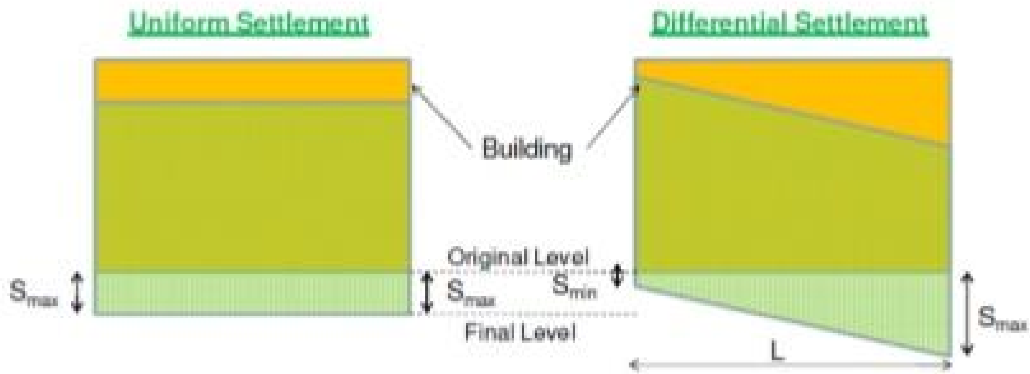
Here,

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

Differential Settlement : It is the maximum difference between two points in a building element. Differential Settlement = Smax – Smin



2(b).A square footing 1.2m*1.2m rests on a saturated clay layer of 4m deep. The soil properties are W_l=30%, γ_{sat}=17.8 KN/m3, w=28% and G=2.68. Determine the primary consolidation settlement if the footing carries a load of 300KN.

Ans:-

$$\sigma_o = \gamma_{sat} Z = 17.8 * \frac{4}{2} = 35.6 kPa$$

$$\Delta\sigma = \frac{300}{(2+1.2+2)^2} = 11.095 kPa$$

$$C_C = 0.009(\omega_L - 10\%) = 0.18$$

$$e_o = \omega G = 0.28 * 2.68 = 0.75041$$

$$H = 4m$$

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

$$= 0.0485\ m$$

3(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 γD_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 Φ to the horizontal.

3(b).Calculate the ultimate bearing capacity of a 2m wide square footing resting on a ground surface of a sand deposit with the following properties:1) unit weight is 18.6 kN/m^3; 2)angle of friction is 38◦. Also calculate ultimate bearing capacity of same footing when the footing is placed at depth of 1m below the ground surface. Take N_q=41.4, N_γ = 42.2 for Φ =38◦. Adopt Terzhagi's equation.

Ans:- Case 1: D_f = 0.

$q_u = 1.3CN_c + 0.4B\gamma N_\gamma + \gamma D_f N_q$

= 0.4 x 2 x 18.6 x 42.2 = 627.936 kN/m2.

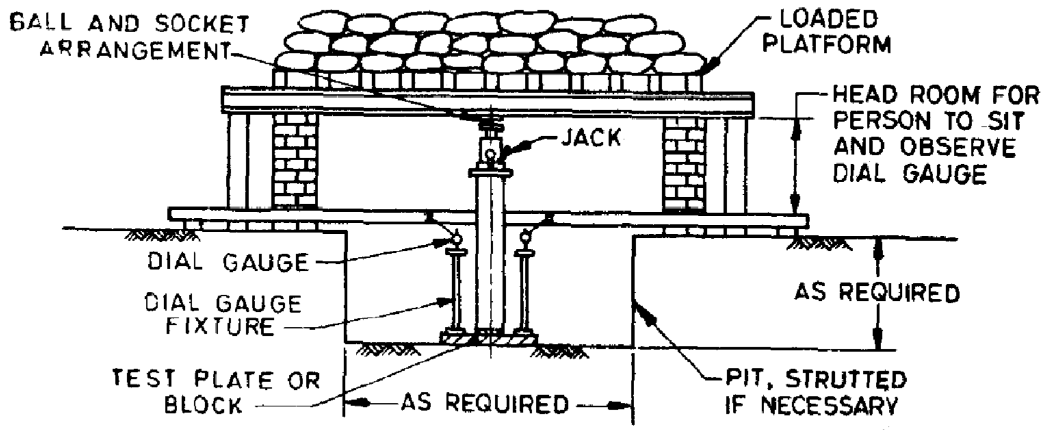
Case 2: D_f = 1m.

$q_u = 1.3CN_c + 0.4B\gamma N_\gamma + \gamma D_f N_q$

$= (0.4 \times 2 \times 18.6 \times 42.2) + (18.6 \times 1 \times 41.4) = 1397.976$ kN/m2.

4(a). With a neat sketch, explain plate load test.

Ans:-



It is a field test for the determination of bearing capacity and settlement characteristics of ground in field at the foundation level. The test involves preparing a test pit up to the desired foundation level. A rigid steel plate, round or square in shape, 300 mm to 750 mm in size, 25 mm thick acts as model footing. Dial gauges, at least 2, of required accuracy (0.002 mm) are placed on plate at corners to measure the vertical deflection. Loading is provided either as gravity loading or as reaction loading. For smaller loads gravity loading is acceptable where sand bags apply the load. In reaction loading, a reaction truss or beam is anchored to the ground. A hydraulic jack applies the reaction load. At every applied load, the plate settles gradually. The dial gauge readings are recorded after the settlement reduces to least count of gauge (0.002 mm) & average settlement of 2 or more gauges is recorded. Load Vs settlement graph is plotted as shown. Load (P) is plotted on the horizontal scale and settlement (Δ) is plotted on the vertical scale. The maximum load at which the shear failure occurs gives the ultimate bearing capacity of soil.

4(b).A 2m x 2m footing is located at a depth of 1.5 m from ground surface in sand. The shear parameters are C = 0 and ϕ=36°. Determine ultimate bearing capacity of soil if (i) water table is well below the foundation level (ii) water table is at base of footing (iii) water table is at the ground surface. Unit wt of soil above water table = 18 kN/m^3 and saturated of soil is 20 kN/m^3. Take Nc = 50.5, Nq = 37.7, Nγ = 48.00.

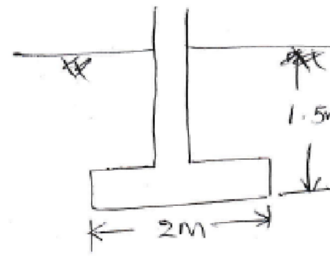
Ans:-

$B = 2m$, $D_f = 1.5m$, $c = 0$, $\phi = 36^\circ$, $\gamma = 18\ kN/m^3$, $\gamma_{sat} = 20\ kN/m^3$,

$N_q = 37.7$, $N_\gamma = 48.00$

$$q_u = 1.3\,cN_c + 0.4\,B\gamma N_\gamma W_\gamma + \gamma D_f N_q W_q$$

(1) <u>WT well below foundation level</u>

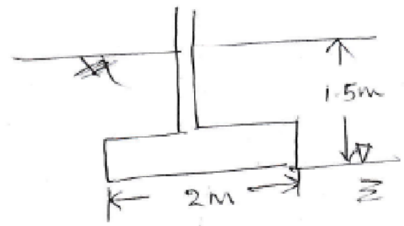


$W_\gamma = 1.0$, $W_q = 1.0$

$$q_u = (0.4 \times 2 \times 18 \times 48) + (18 \times 1.5 \times 37.7)$$

$$= 1709.1\ kN/m^2$$

(2) <u>WT at base of footing</u>



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

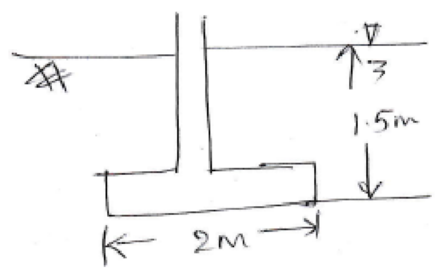
$$W_q = \frac{1}{2}\left[1 + \frac{1.5}{1.5}\right] = 1.0$$

$$q_u = 0.4\,B\gamma_{sub} N_\gamma W_\gamma + \gamma D_f N_q W_q$$

$$= 0.4 \times 2 \times (20-10)\,48 \times 0.5 + (18 \times 1.5 \times 37.7 \times 1.0)$$

$$= 1209.9\ kN/m^2$$

3) <u>WT is at ground</u> surface



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

$$W_q = 0.5$$

$$q_u = 0.4\,B\gamma_{sub} N_\gamma W_\gamma + \gamma_{sub} D_f N_q W_q$$

$$= 0.4 \times 2 \times (20-10) \times 48 \times 0.5 + (20-10) \times 1.5 \times 37.7 \times 0.5$$

$$= 474.75\ kN/m^2$$

5(a).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, γ D represents the overburden pressure at foundation level where γ 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.

(Q14) A 3m square footing is located in dense sand at a depth of 2m. Determine the safe bearing capacity using Terzhaghi's theory, for the following WT positions: (a) at GL (b) at footing level (c) at 1m below the footing. The moist unit weight of sand above the WT is l8kN/m^3, and γ_{sat} = l8kN/m^3. Φ=26◦, γ_w = l0kN/m^3, FOS = 3.

Φ	**N_c**	**N_q**	**N_γ**
15	**12.9**	**4.4**	**2.5**
20	**17.7**	**7**	**5**
25	**25.1**	**12.7**	**9.7**

Ans:- Since this is a case of LSF, tan Φ= (2/3) * tan 26

Hence we get Φm = 18. ɣsub = 8 Kn/m3

For Φ = 18, Nq = 5.96, Nɣ = 4.

Ultimate bearing capacity qu = 0.4Bɣ NɣWɣ + ɣDfNqWq

Safe bearing capacity qs = (qu - ɣDf) / FOS + ɣDf

<u>Case 1:-</u> Wq = 0.5, Wɣ = 0.5, qu = 66.88 Kn/m^2 & qs = 32.96 Kn/m^2

<u>Case 2:-</u> Wq = 1.0, Wɣ = 0.5, qu = 233.76 Kn/m^2 & qs = 101.92 Kn/m^2

Case 3:- $W_q = 1.0$, $W_\gamma = 0.66$, $\gamma_{avg} = 11.33$ Kn/m^3, qu = 250.45 Kn/m^2 & qs = 107.48 Kn/m^2

5(b). A 3m square footing is located in dense sand at a depth of 2m. Determine the safe bearing capacity using Terzhaghi's theory, for the following WT positions: (a) at GL (b) at footing level (c) at 1m below the footing. The moist unit weight of sand above the WT is l8kN/m^3, and γ_{sat} = l8kN/m^3. Φ=26°, γ_w = l0kN/m^3, FOS = 3.

Φ	N_c	N_q	N_γ
15	12.9	4.4	2.5
20	17.7	7	5
25	25.1	12.7	9.7

Ans:- Since this is a case of LSF, tan Φ= (2/3) * tan 26

Hence we get Φm = 18. γ_{sub} = 8 Kn/m3

For Φ = 18, Nq = 5.96, N_γ = 4.

Ultimate bearing capacity qu = $0.4B\gamma N_\gamma W_\gamma + \gamma D_f N_q W_q$

Safe bearing capacity qs = (qu - γDf) / FOS + γDf

Case 1:- $W_q = 0.5$, $W_\gamma = 0.5$, qu = 66.88 Kn/m^2 & qs = 32.96 Kn/m^2

Case 2:- $W_q = 1.0$, $W_\gamma = 0.5$, qu = 233.76 Kn/m^2 & qs = 101.92 Kn/m^2

Case 3:- $W_q = 1.0$, $W_\gamma = 0.66$, $\gamma_{avg} = 11.33$ Kn/m^3, qu = 250.45 Kn/m^2 & qs = 107.48 Kn/m^2