GEOTECHNICAL ENGINEERING-II

Internal Assesment Test- I (SOLUTIONS)

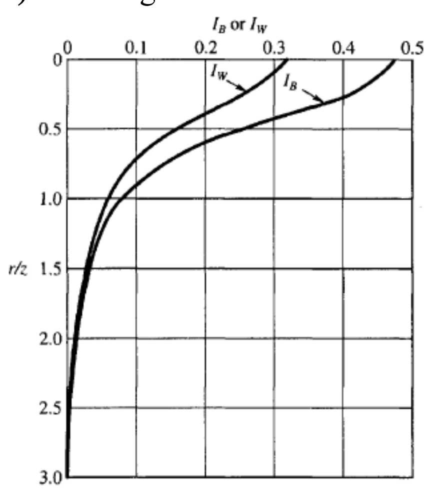
Q1.(a) Distinguish between Boussinesq's and Westergaard's theories of stress distribution.

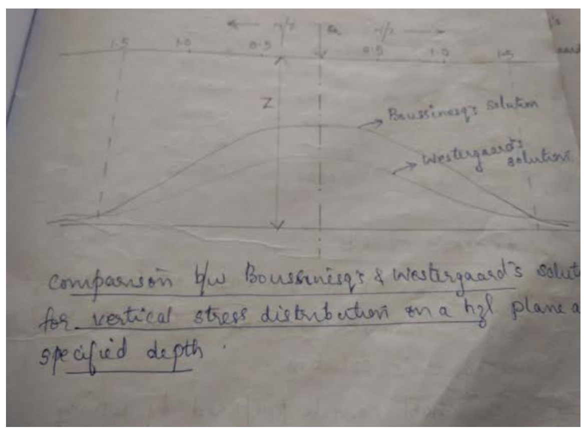
Ans:- Boussinesq's theory:-

1) Assumes that the soil medium is isotropic.
2) Deals with homogeneous medium of soils
3) Does not consider poisson's ratio and assumes to be zero.
4) The vertical stress value obtained is higher
5) Boussinesq's influence factor is high

Westergaard's theory:-

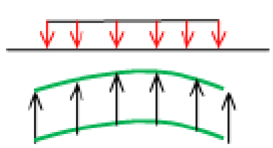
1) Assumes that the soil medium is anisotropic
2) Deals with thin sheets of rigid material sandwiched in a homogeneous medium.
3) Considers poisson's ratio and it ranges between 0 to 0.5
4) The vertical stress value obtained is lower compared to Boussinesq's theory.
5) Westergaard's influence factor is low compare to Boussinesq's influence factor.



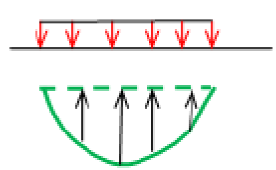


Q1.(b) Explain contact pressure distribution in soils.

Ans: In sandy soils:-



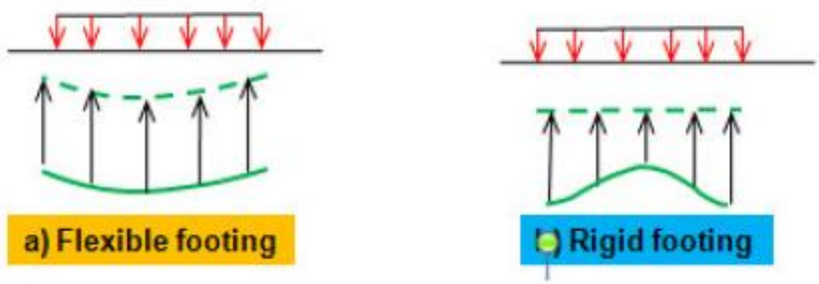
a) Flexible footing



b) Rigid footing

Fig a & b shows the qualitative contact pressure distribution under flexible and rigid footing resting on a sandy soil and subjected to a uniformly distributed load q. when the footing is flexible, the edges undergo a large settlement than at centre. The soil at centre is confined and therefore has a high modulus of elasticity and deflects less for the same contact pressure. The contact pressure is uniform. When the footing is rigid the settlement is uniform. The contact pressure is parabolic with zero intensity at the edge sand maximum at the centre.

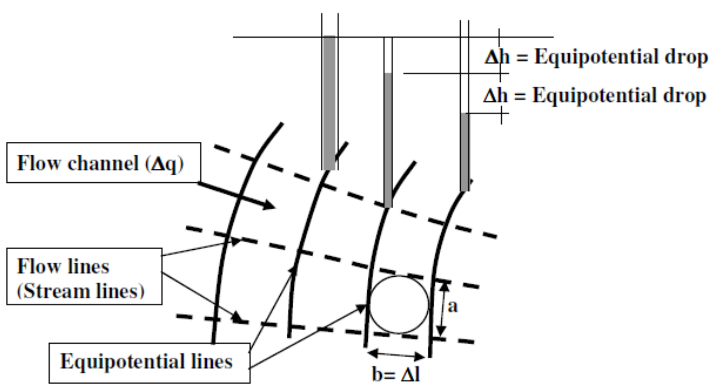
In clayey soils:-



When the footing is flexible, it deforms into the shape of a bowel, with the maximum deflection at the centre. The contact pressure distribution is uniform If the footing is rigid, the settlement is uniform. The contact pressure distribution is minimum at the centre and the maximum at the edges(infinite theoretically). The stresses at the edges in real soil cannot be infinite as theoretically determined for an elastic mass.

Q2.(a) What is a flow net? Explain their properties.

Ans:- A flow net is a graphical representation of a flow field and comprises a family of flow lines and equipotential lines.



Characteristics of flow nets

1. Flow lines or stream lines represent flow paths of particles of water.

2. Flow lines and equipotential line are orthogonal to each other.

3. The area between two flow lines is called a flow channel.

4. The rate of flow in a flow channel is constant (Δq).

5. Flow cannot occur across flow lines.

6. An equipotential line is a line joining points with the same head.

7. The velocity of flow is normal to the equipotential line.

8. The difference in head between two equipotential lines is called the potential drop or head loss (Δh).

Q2.(b) A flow net drawn for seepage flow below a dam has 4 channels and 9 equi-potential lines. There is 8 m of water on upstream side and no water on downstream. If the soil below the dam has Kx = 4 × 10^{-4} cm/s and Ky = 2 × 10^{-4} cm/s, calculate the seepage loss per day for every 100 m length of the dam.

Ans:- *Data given :*

$H = 8\ m,\ N_d = 8,\ N_f = 4,\ k = sqrt(\ k_x\ X\ \ k_y) = 2.83\times10^{-4}\times\ 10^{-2}\ m / sec$

$$Q = k \times H \times \left(\frac{N_f}{N_d} \right)$$

$= 2.83\times10^{-2}$ x 60 x 60 x 24 x 4 x 100 x 8 x 10^{-4} x 10^{-1}

= 78.2 m^3/day.

Q3.(a) List and explain the causes of slope failure.

Ans:- 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.

Q3.(b) A point load of 500 kN due to monument acts on the ground surface. Calculate the vertical pressures at point 5m directly below the load and at a distance of 4m from the load. Assume μ = 0. Use (1) Boussinesq's analysis (2) Westergaard's analysis.

Ans:-

3 b) $Q = 500\ kN$, $z = 5m$, $r = 4m$, $\mu = 0$.

Boussinesq's analysis –

vertical pressure directly below 5m $= 0.4775 \times \frac{500}{5^2} = 9.55\ kN/m^2$

$$(\sigma_z) \text{ at } r = 4m = \frac{3Q}{2\pi}\left[\frac{1}{1+\left(\frac{r}{z}\right)^2}\right]^{5/2} \times \frac{1}{z^2}$$

$$= \frac{3\times 500}{2\pi}\left[\frac{1}{1+\left(\frac{4}{5}\right)^2}\right]^{5/2} \times \frac{1}{5^2} = 2.77\ kN/m^2$$

Westergaards

$$C = \sqrt{\frac{1-2\mu}{2-2\mu}} = \frac{1}{\sqrt{2}}$$

$$\sigma_z \text{ directly below } 5m = \frac{Q}{\pi z^2} = \frac{500}{\pi \times 5^2} = 6.366\ kN/m^2$$

$$\sigma_z \text{ at } r = 4m \ \& \ \mu = 0 = \frac{Q}{\pi z^2} \times \frac{1}{\left(1+2(r/z)^2\right)^{3/2}}$$

$$= \frac{500}{\pi \times 5^2} \times \frac{1}{\left(1+2(4/5)^2\right)^{3/2}} = 1.849\ kN/m^2$$

Q4.(a) Explain the graphical method of locating phreatic line in an earth dam with horizontal filter.

Ans:- The seepage line or phreatic line may be defined as the line above which there is no hydrostatic pressure and below which there is hydrostatic pressure. Therefore phreatic line is the top flow line which separates saturated and unsaturated zones within the body of the earth dam.

The following are the steps in the graphical determination of the top flow line for a homogeneous dam with a toe filter:

1.Draw the earth dam section and upstream water level (***H***) to some convenient scale.

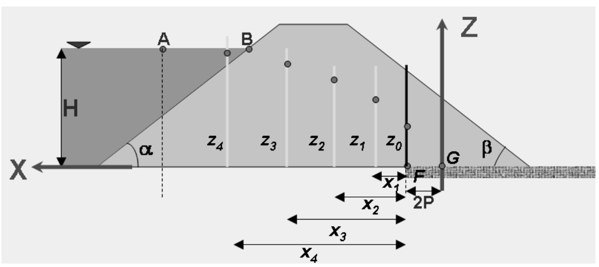
2. Locate *Point-**B**,* the point on the upstream slope coinciding with water level.

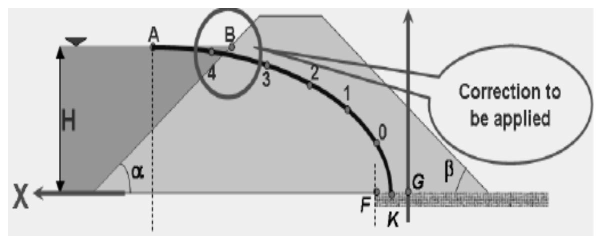
3. Let Δ be the horizontal distance between *point-* ***B*** and upstream heel of the dam. Locate *Point-**A*** at a distance of **0.3** times Δ from *Point-**B*** on the water surface. That is distance ***AB*** is **0.3**Δ.

4.Select *F* as the focus of the parabolic phreatic line, *Point-**F*** is located at the intersection of the bottom flow line and the downstream toe filter. Let horizontal distance between *points* ***A & F*** be ***d*** i.e., ***AF = d.***

5.Locate *Point-**G*** on the directrix of the parabola, located a distance ***2P*** from the focal point, *Point-**F***, that is ***FG = 2P.***

6. Select base of the dam and directrix as ***X & Z*** axes.





7.By choosing suitable values of ***z***-ordinates, compute the ***x***-ordinates of the base parabola. Thus $z_1,\ z_2,\ z_3,\ z_4......$ are computed for the ordinates $x_1,\ x_2,\ x_3,\ x_4......$ respectively.

8. Join all such located points to get basic parabola. This parabola meets toe filter (equipotential line) orthogonally at midpoint of ***FG*** that is at a distance ***p*** from ***F*** (vertex ***K*** of the parabola). Joint points ***K-0-1-2-3-4-A*** to get parabola ***ABK.***

9. Apply modification to phreatic line at the entry *Point-**B*** on the upstream slope which is an equipotential line. Draw line perpendicular to upstream slope starting from ***B*** and meets the base parabola smoothly and tangentially at a convenient point say, ***C.*** Complete the phreatic line ***BCK*** (top flow line) by joining ***BC*** erase remaining portion of the base parabola.

Q4.(b) A rectangular area 4m x 3m is uniformly distributed with a load intensity of 10t/m^2 at the ground surface. Calculate the vertical pressure at a point 3m below one of its corners using equivalent area method.

Ans:-

4(b) $Q = 10 \times 4 \times 3 = 120\ t = \underline{12\ KN}$

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

$$= \frac{3 \times 12}{2\pi} \times \frac{1}{5^2}\left[\frac{1}{1+(4/5)^2}\right]^{5/2} = 0.0665\ KN/m^2$$

$$= \underline{0.665\ t/m^2}$$

Q5.(a) Define isobar. Construct an isobar for a vertical stress of 40 kN/m^2 when ground surface is subjected to a concentrated load of 1000 kN.

Ans:- 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.

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

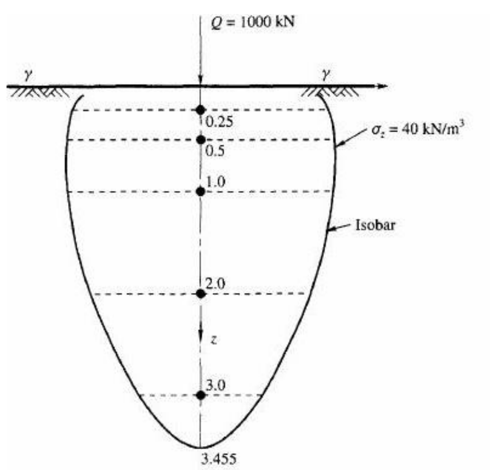
We may now write by rearranging an equation for the radial distance r as

$$r = \sqrt{z}\sqrt{\left(\frac{3Q}{2\pi z^2 \sigma_z}\right)^{2/5} - 1}$$

σz = intensity of vertical stress just below the point load Q, at depth z & r = radial distance.

Now for Q = 1000 kN, σ_z = 40 kN/m^2, we obtain the values of r_1, r_2, r_3, etc. for different depths z_1, z_2, z_3, etc. The values so obtained are

z (m)	r (m)
0.25	1.34
0.50	1.36
1.0	1.30
2.0	1.04
3.0	0.60
3.455	0.00

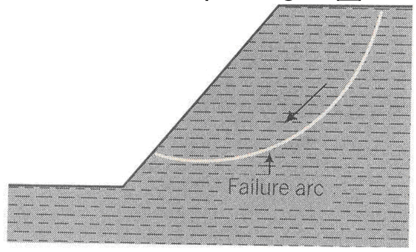


Q6.(a) Explain with neat sketches the types of failure in finite slopes.

Ans:- The various types of failure in finite slopes are:

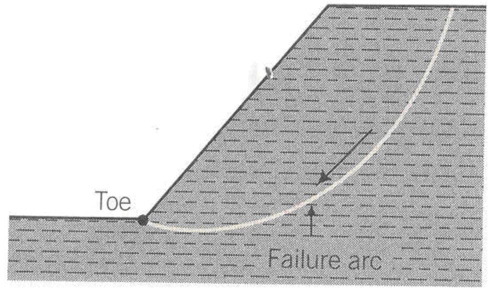
1. Face (Slope) failure
2. Toe failure

3. Base failure
1. **Face (Slope) Failure:** This type of failure occurs when the slope angle (_)



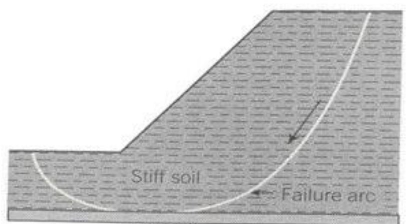
Slope slide

is large and when the soil at the toe portion is strong.



Toe slide

2. **Toe Failure:** In this case the failure surface passes through the toe. This occurs when the slope is steep and homogeneous.
3. **Base Failure:** In this case the failure surface passes below the toe. This generally occurs when the soil below

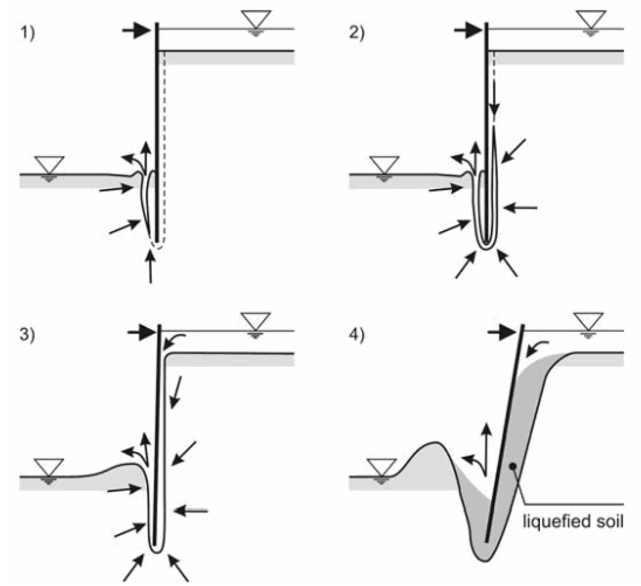


Base slide

the toe is relatively weak and soft.

Q6.(b) Explain briefly piping failures.

Ans:- *<u>Hydraulic Heave or Piping:-</u>*Many dams on soil foundations have failed because of the sudden formation of a piped shaped discharge channel. As the store water rushes out, the channel widens and catastrophic failure results. This results from erosion of fine particles due to water flow. Another situation where flow can cause failure is in producing 'quicksand' conditions. This is also often referred to as piping failure.



Piping Failure : 1) initiation and first deterioration, 2) regressive erosion, 3)formation of flow channel, 4) liquefaction and collapse

*Backward erosion Piping:-*It is caused by the percolating water and the piping begins when the exit gradient exceeds the critical gradient. The soil at the exit is removed by the percolating water. When the soil gets removed the flow gets modified. As there is more concentration in the remaining soil mass, there is an increase in exit gradient.