CBCS SCHEME

USN | | | | | | | | | | 17CV53

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Applied Geotechnical Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Use of IS:6403 permitted.

Module-1

1 a. Enumerate the objectives of soil investigation. **(06 Marks)**

b. Explain the wash boring method of soil exploration with a neat sketch. **(07 Marks)**

c. With a neat sketch of soil sampler, define:
i) Area ratio ii) Inside clearance iii) Outside clearance iv) Recovery ratio. **(07 Marks)**

OR

2 a. Distinguish between disturbed, undisturbed and representative samples, for which type of test the samples are suited. **(06 Marks)**

b. What is meant by drainage and dewatering? Explain electro-osmosis method of dewatering. **(07 Marks)**

c. Explain the Hvorslev's method of locating the ground water table. **(07 Marks)**

Module-2

3 a. Distinguish between Bousinessq and Westergaard's theory of stress distribution. **(06 Marks)**

b. Explain equivalent point load method of determining vertical stress at a point within loaded area. **(07 Marks)**

c. A load of 1000kN acts as a point load at the ground surface. Estimate the stress at a point 2m below and 4m away from the point of action of the load by Bousinenq's formula. Compare with Westergaard's formula. **(07 Marks)**

OR

4 a. A concentrated load 1000kN acts at the ground surface. Construct a 25% isobar. **(06 Marks)**

b. Explain the construction and use of Newmark's chart. **(07 Marks)**

c. A saturated clay 8m thick underlies a proposed new building. The existing overburden pressure at the centre of clay layer is 300kPa and load due to the new building increases the pressure by 200kPa. The liquid limit of the soil is 75%, water content – 50% and G = 2.7. Estimate the consolidation settlement. **(07 Marks)**

Module-3

5 a. Distinguish between active and passive earth pressure. What are the assumptions made in the Rankine's earth pressure theory? **(06 Marks)**

b. Explain the Culmann's graphical method of determining the active Earth pressure. **(07 Marks)**

c. A Smooth vertical wall of height 4.5m retains a cohesion less backfill with $\phi = 30°$, void ratio = 0.62 and G = 2.7. If the soil is completely dry, draw the earth pressure distribution on the wall. If the water table rises to the top of the soil, compute the total earth pressure on the wall. **(07 Marks)**

OR

6 a. Explain the causes for a slope failure. Explain with neat sketch the different modes of slope failure. **(06 Marks)**

b. Explain the method of slices for slope stability analysis. **(07 Marks)**

c. Calculate the factor of safety with respect to cohesion of clay, the slope laid at 1 in 2 to a length of 11m. If the angle of internal friction $\phi = 10°$, Taylor's stability number is 0.064, $c = 20kN/m^2$ and $\gamma = 19kN/m^2$. Determine the critical height of the slope. Determine the critical height of the slope in this soil. **(07 Marks)**

Module-4

7 a. What are the assumptions made in Terzaghi's theory? Write the expression for ultimate bearing capacity of strip footing, square and circular footing. **(10 Marks)**

b. The footing of a column 2.5 × 2.5m is founded at a depth of 1.5m on a cohesive soil of unit weight $18kN/m^3$. Take $C = 30kN/m^2$, $\phi = 0$. What is the safe load for this footing? **(10 Marks)**

OR

8 a. With the help of neat sketch, explain the effect of water table on the bearing capacity of soil. **(10 Marks)**

b. Explain standard penetration test with suitable corrections. How do you access b.c. of shallow footings on sand using SPT test data? **(10 Marks)**

Module-5

9 a. List and explain the classification of piles based on function and material. **(10 Marks)**

b. A square pile group of 9 piles of 250mm diameter is arranged with a pile spacing of 1m. The length of the pile is 9m. The unit cohesion of clay is $75kN/m^2$. Neglecting bearing at the tip of the piles. Determine the group capacity. Assume adhesion factor of 0.75ϕ. **(10 Marks)**

OR

10 a. Write a note on negative skin friction. **(10 Marks)**

b. Write a note on under-reamed piles. How can the ultimate load carrying capacity of under-reamed piles can be estimated. **(10 Marks)**

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FIFTH SEMESTER B.E. DEGREE EXAMINATION, JAN/FEB 2021

APPLIED GEOTECHNICAL ENGINEERING (17CV53)

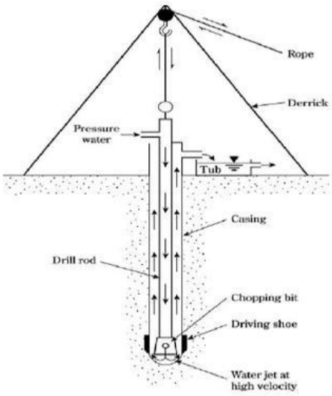
1. ***(a) Ans:-*** Soil investigations are done to obtain the information that is useful for one or more of the following purposes:

1. To know the geological condition of rock and soil formation.
2. To establish the groundwater levels and determine the properties of water.
3. To select the type and depth of foundation for proposed structure
4. To determine the bearing capacity of the site.
5. To estimate the probable maximum and differential settlements.
6. To predict the lateral earth pressure against retaining walls and abutments.
7. To select suitable construction techniques
8. To predict and to solve potential foundation problems
9. To ascertain the suitability of the soil as a construction material.
10. To determine soil properties required for design
11. Establish procedures for soil improvement to suit design purpose
12. To investigate the safety of existing structures and to suggest the remedial measures.

1. (b) Ans:- Wash boring relies on relatively little drilling action and can form a hole primarily by jetting. This can be undertaken with light equipment without the need for a drilling rig.

Suitable for all types of soils but not for rocks and boulders.

- ✓ It consists of driving a casing through which a hollow drill rod with a sharp chisel at the lower end is inserted.
- ✓ Water is forced under pressure through the drill rod.
- ✓ The resulting chopping and jetting action of the bit and water disintegrates soil.
- ✓ Cuttings are then forced up through the spacing between drill rod and casing.



1. ***(c) Ans:-***

$$\text{Area ratio } A_r = \frac{Max. Cross\ sectional\ area\ of\ the\ cutting\ edge}{Area\ of\ the\ soil\ sample}$$

$$A_r = \frac{{D_2}^2 - {D_1}^2}{{D_1}^2} x\ 100$$

Where, D_1 = inner diameter of the cutting edge, D_2 = outer diameter of the cutting edge
For obtaining good quality undisturbed samples, the area ratio should be less than or equal to 10%.

Inside Clearance

$$Ci = \frac{D_3 - D_1}{D_1} x\ 100$$

Where D_3 = inner diameter of the sample tube
It helps in reducing the frictional drag on the sample, and also helps to retain the core. For an undisturbed sample, the inside clearance should be between 0.5 and 3%.

Outside Clearance

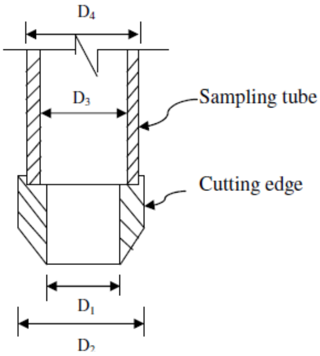
Where D_4 = outer diameter of the sample tube
Outside clearance facilitates the withdrawal of the sample from the ground. For reducing the driving force, the outside clearance should be as small as possible. Normally, it lies between zero and 2%.

$$Co = \frac{D_2 - D_4}{D_4} x\ 100$$

Recovery Ratio

$$R_r = \frac{L}{H}$$

Where L = length of the sample within the tube, and H = Depth of penetration of the sampling tube.



2. ***(a) Ans:-***

Non-Representative samples:- Non-Representative soil samples are those in which neither the in-situ soil structure, moisture content nor the soil particles are preserved. They are not representative**.** They cannot be used for any tests as the soil particles either gets mixed up or some particles may be lost. E.g: Samples that are obtained through wash boring or percussion drilling.
Disturbed soil samples:- Disturbed soil samples are those in which the in-situ soil structure and moisture content are lost, but the soil particles are intact. They are representative**.** They can be used for grain size analysis, liquid and plastic limit, specific gravity, compaction tests, moisture content, organic content determination and soil classification test performed in the lab. E.g., obtained through cuttings while auguring, grab, split spoon (SPT), etc.
Undisturbed soil samples:- Undisturbed soil samples are those in which the in-situ soil structure and moisture content are preserved. They are representative and also intact. These are used for consolidation, permeability or shear strengths test. In sand, it is very difficult to

obtain undisturbed sample. Obtained by using Shelby tube (thin wall), piston sampler, surface (box), vacuum, freezing, etc.

2. (b) Ans:-

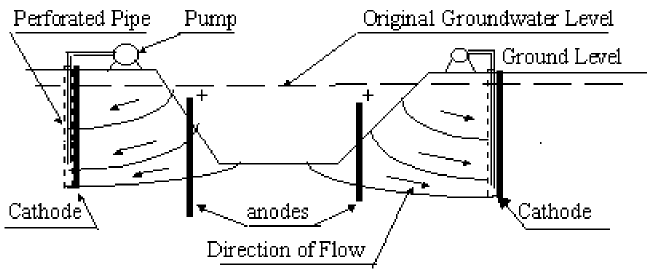


Fig. 8.8 Control of Groundwater by Electro-Osmosis Methods

Electro-osmosis is defined as “the movement of water (and whatever is contained in the water) through a porous media by applying a direct current (DC) field”. It is the only effective method of dewatering in deep clay soils. As the surface of fine grained soil particles causes negative charge, the positive ions in solution are attracted towards the soil particles and concentrate near the surfaces. Upon application of the electro motive force between two electrodes in a soil medium the positive ions adjacent to the soil particles and the water molecules attached to the ions are attracted to the cathode and are repelled by the anode. The free water in the interior of the void spaces is carried along to the cathode by viscous flow. By making the cathode a well, water can be collected in the well and then pumped out.

2.(c) Ans:-

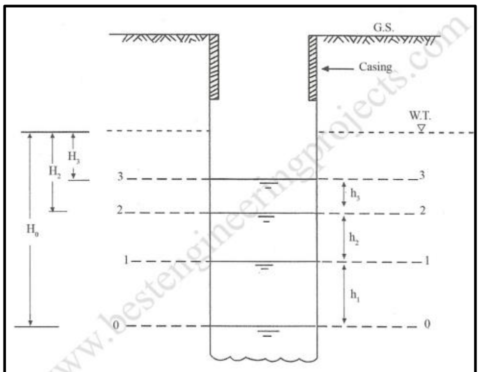


Fig 1 Water Level Location by Rising Water Table Method

- Let time be t_0 when WTL is at depth H_0 below normal water level.
- Let successive rise in water levels be h_1, h_2, h_3 etc. at times t_1, t_2, t_3 respectively.
- Difference in time is kept a constant.
- $H_0 – H_1 = h_1$; $H_1 - H_2 = h_2$; $H_2 – H_3 = h_3$
- Depth of water level in the casing from the normal WTL can be computed as

$$H_0 = \frac{h_1^2}{h_1 - h_2}$$

$$H_1 = \frac{h_2^2}{h_1 - h_2}$$

$$H_2 = \frac{h_3^2}{h_2 - h_3}$$

- Let the corresponding depths of WTL below the ground surface be h_{w1}, h_{w2}, h_{w3} etc.
  First estimate, $h_{w1} = H_w - H_0$
  Second estimate, $h_{w2} = H_w - (h_1 + h_2) - H_1$
  Third estimate, $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2$
  H_w = depth of water level in the casing from ground surface.

Depth of GWT, $h_w = \frac{h_{w1}+h_{w2}+h_{w3}}{3}$

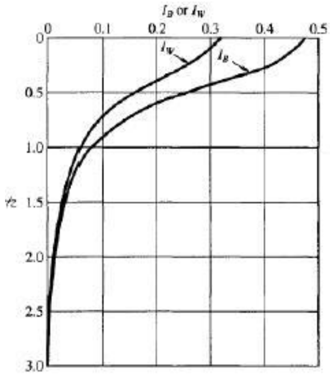
3. (a) Ans:-

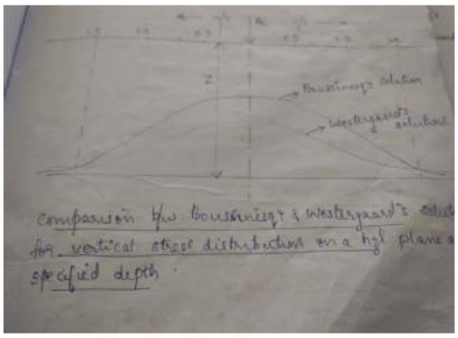
Boussinesq's theory:-

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

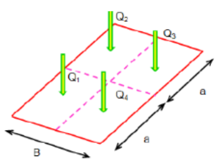
Westergaard's theory:-

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.





3.(b) Ans:- The vertical stress at a point under a loaded area of any of any shape can be determined by dividing the loaded area into small area and replacing the distributed load on each on small area by an equivalent point load acting at the centroid of the small area. The principle of superposition is then applied and the required stress at a specified point is obtained by summing up the contributions of the individual. Point loads from each of the units by applying the approximate point load formula, such as that of Boussinesq" s or Westergaard" s. As shown in the above figure, if a square area of size B is acted on by a uniform load q, the same area can be divided into four small area. And the load on each area can be converted into an equivalent point load assumed to act at its centroid. Then the vertical stress at any point below or outside the loaded area is equal to the sum of the vertical stresses due to these equivalent point loads. Then



$$\sigma_Z = \frac{[Q_1(I_B)_1 + Q_2(I_B)_2 + Q_3(I_B)_3 + \dots\dots\dots + Q_n(I_B)_n]}{Z^2}$$

$$\sigma_Z = \frac{1}{Z^2} \sum_{i=1}^{n} Q_i (I_B)_i$$

3. (c) Ans:- Boussinesq's analysis:

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

$$\underline{\boldsymbol{\sigma_z = 86.56\ kN/m2}}$$

4. (a) Ans:

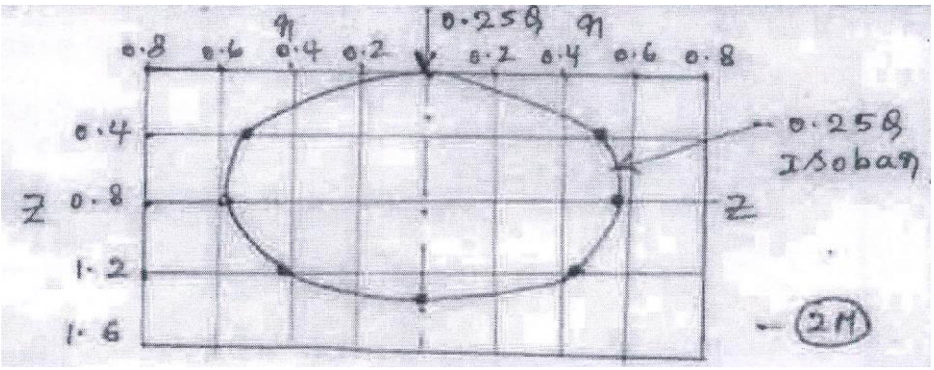
For Boussinesq's point load, $\sigma_z = \frac{Q}{z^2} I_B$ — (2M)

$\sigma_z = 0.25Q$ $\quad \therefore I_B = 0.25 z^2$

For $r = 0$; $I_B = 0.4775$, $\therefore z = \sqrt{\frac{0.4775}{0.25}} = 1.382$

Isobar cross the line of action at 1.382 m — (2M)

Depth z (m)	Influence factor I_B	$\frac{r}{z}$	r	σ_z
0.4	0.04	1.3025	0.5208	0.25Q
0.8	0.16	0.7405	0.592	0.25Q
1.2	0.36	0.345	0.414	0.25Q
1.382	0.4775	0	0	0.25Q

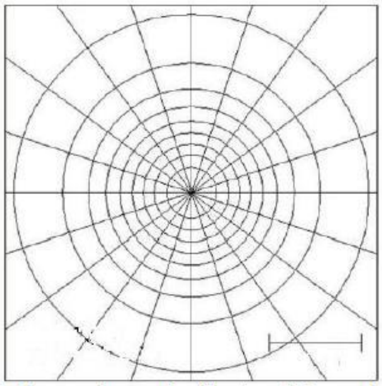


4.(b) Ans:-

For the specified depth z, say 10 m, the radii of the circles, R, are calculated from the equation

$$\frac{R}{z} = +\sqrt{\left(1-\frac{\sigma_z}{q}\right)^{-\frac{2}{3}} - 1}$$

for relative radii given by, where, R/z is the relative radii, σ_z =vertical stress at any depth, q = load intensity.
The circles are then drawn to a convenient scale (say, 1 cm = 2 m or 1:200). A suitable number of uniformly spaced rays (to get required influence value) are drawn, emanating from the center of the circles. The resulting diagram will appear as shown in below. On the figure is drawn a line AB, representing the depth z to the scale used in drawing the circles. If the scale used is 1 cm = 2 m, then AB will be 5 cm. The influence value for this chart will be I = (1/c x s). The same chart can be used for other values of the depth "z" . The length AB is taken equal to the depth "z "of the given problem and to that scale the loaded diagram is plotted on a tracing sheet to be superimposed later on the Newmark" s chart to obtain the vertical stress at the desired point.



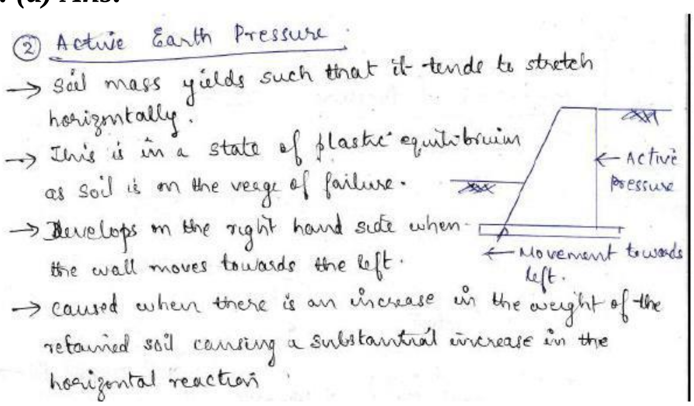
4. (c) Ans:-

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

$$S_c = \frac{0.585}{1+1.355} \times 8 \times \log_{10}\left(\frac{300+200}{300}\right)$$

$$S_c = 0.4408\ m = 440.8mm$$

5. (a) Ans:-



② Active Earth Pressure
→ Soil mass yields such that it tends to stretch horizontally.
→ This is in a state of plastic equilibrium as soil is on the verge of failure.
→ Develops on the right hand side when the wall moves towards the left.
→ Caused when there is an increase in the weight of the retained soil causing a substantial increase in the horizontal reaction.

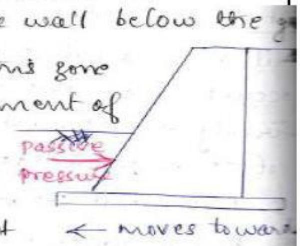
③ Passive Pressure

→ Occurs when the wall movement tend to compress the soil horizontally.

→ It is a condition of limiting equilibrium.

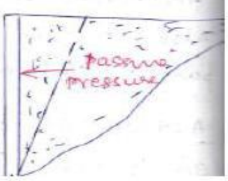
→ Develops on the left side of the wall below the g

level because the soil in this zone is compressed when the movement of the wall is towards left.



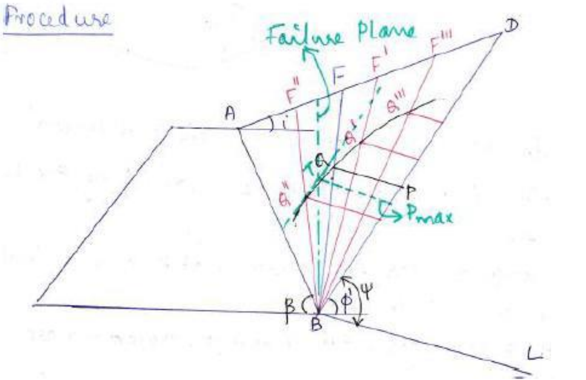
→ Develops on the right side of the wall when the movement of the wall is towards right.

Eg. Pressure acting on anchor block.



5. (b) Ans:-

Procedure



From B, a line BD is drawn at an angle ϕ' to the h
As the weight of the wedge is plotted along this line,
s also known as the weight line.

A line BL is drawn at an angle ψ with the line BD,
hat $\psi = \beta - \delta$

A failure surface BF is assumed & the weight W of the failure wedge ABF is computed.

④ The weight (W) of the wedge is plotted along BD such that BP = W.

⑤ From P, draw a line PQ parallel to BL to intersect the failure surface BF at Q.

⑥ The line PQ represents the magnitude of P_a required to maintain equilibrium for the assumed failure plane.

⑦ Similarly several other failure planes BF'', BF', BF''' etc are assumed & the procedure is repeated & thus the points Q'', Q', Q''' etc are located.

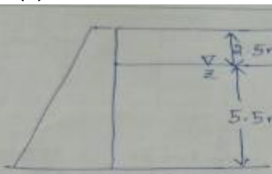
⑧ A smooth curve is drawn joining the points Q'', Q, Q', Q'''. This curve is called culmann's line.

⑨ A line (shown dotted) is drawn tangential to the culmann line & parallel to BD. Point T is the point of tangency.

⑩ The magnitude of the largest value (P_{max}) of P_a is measured from the tangent point T to the line BD and parallel to BL. It is equal to Coulomb's active pressure (P_a).

⑪ The actual failure plane passes through the point T.

5. (c) Ans:-

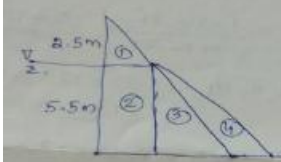


c = 0
e = 0.6
$\phi = 30°$
G = 2.65

$\gamma_{sub} = \frac{(G-1)\gamma_w}{1+e} = 10.116\ kN/m^3$

$\gamma_d = \frac{G\gamma_w}{1+e} = 16.25\ kN/m^3$

$K_a = \frac{1-\sin 30°}{1+\sin 30°} = 0.33$



$p_1 = K_{a_1} \times \gamma_d \times 2.5 = 13.406\ kN/m^2$

$p_2 = K_{a_1} \times \gamma_d \times H_1 = 13.406\ kN/m^2$

$p_3 = K_{a_1} \times \gamma_{sub} \times H_2 = 0.33 \times 10.116 \times 5.5 = 18.36\ kN/m^2$

$p_4 = \gamma_w \times H_2 = 9.81 \times 5.5 = 53.955\ kN/m^2$

$P_1 = \frac{1}{2} \times 13.406 \times 2.5 = 16.757\ kN/m^2$

$P_2 = 13.406 \times 5.5 = 73.73\ kN/m^2$

$P_3 = \frac{1}{2} \times 18.36 \times 5.5 = 50.49\ kN/m^2$

$P_4 = \frac{1}{2} \times 53.955 \times 5.5 = 148.376\ kN/m$

$P = P_1 + P_2 + P_3 + P_4 = 289.353\ kN/m$

$P \times \bar{x} = P_1 \times \left(5.5 + \frac{2.5}{3}\right) + P_2 \times \left(\frac{5.5}{2}\right) + P_3 \times \left(\frac{5.5}{3}\right) + P_4 \times \left(\frac{5.5}{3}\right)$

$= 106.127 + 202.76 + 92.565 + 272.02$

$\bar{x} = 2.33\ m$ from base.

6. (a) Ans:-

1.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 build-up 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.

Soil slope failures are generally of four types :

1. Translational Failure
2. Rotational Failure
3. Wedge Failure
4. Compound Failure

Translational Failure

- Translation failure occurs in the case of infinite slopes and here the failure surface is parallel to the slope surface.
- This type of failure can be observed in slopes of layered materials or natural slope formations.

Rotational Failure

- In the case of rotational failure, the failure occurs by rotation along a slip surface and the shape thus obtained in slip surface is curved. Failed surface moves outwards and downwards.

Rotational failure may occur in three different ways :

1. Face failure or slope failure
2. Toe failure
3. Base failure

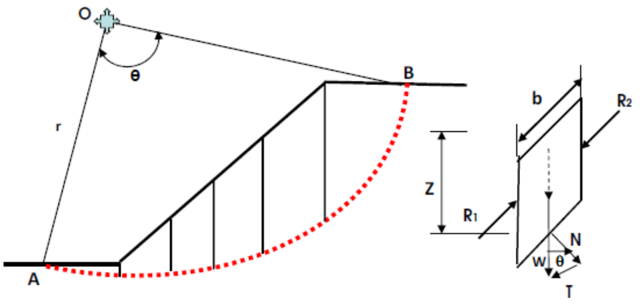
Wedge Failure

- Wedge failure, also known as block failure or plane failure, generates a failure plane that is inclined.
- This type of failure occurs when there are fissures, joints, or weak soil layers in slope, or when a slope is made of two different materials.

Compound Failure

- A Compound failure is a combination of translational slide and rotational slide.
- In this case, the slip surface is curved at two ends like rotational slip surface and flat at central portion like in translational failure.

6. (b) Ans:-



Slip circle divided into slices

FBD on a typical slice

For C-Φ soils the undrained strength envelope shows both c and Φ values. The total stress analysis can be adopted. The procedure is follows

1. Draw the slope to scale
2. A trail slip circle such as AB with radius „r‟ is drawn from the center of rotation O.
3. Divide the soil mass above the slip surface into convenient number of slices (more than 5 is preferred)
4. Determine the area of each slice A1, A2, -------, An; where A = width of the slice X mid height = b X Z
5. Determine the total weight W including external load if any as W = ɣ b Z = ɣ A ; Where, ɣ = unit weight, b = width of slice, Z = height of slice.

The reactions R1 and R2 on the sides of the slice are assumed equal and therefore do not have any effect on stability.

6. The weight W of the slice is set –off at the base of the slice. The directions of its normal component „N‟ and the tangential component „T‟ are drawn to complete the vector triangle.

$N = W \cos\delta$, $T = W \sin\delta$

7. The values of N and T are scaled off for each of the slices.
8. The factor of safety is calculated as follows:

Sliding moment $= r\,\Sigma T$ (*reckoned positive if clockwise*)

Re *storing moment* $= r\,(c\,r\theta + \Sigma N \tan\phi)$ (*reckoned positive if counterclockwise*)

$$Factor\ \ of\ safety, FS = \frac{(c\,r\,\theta + \sum N\ \tan\phi)}{\sum T}$$

7. (a) Ans:-

1) Soil is homogeneous and Isotropic.
2. The shear strength of soil is represented by Mohr Coulombs Criteria.
3. The footing is of strip footing type with rough base. It is essentially a two dimensional plane strain problem.
4. Elastic zone has straight boundaries inclined at an angle equal to Φ to the horizontal.
5. Failure zone is not extended above, beyond the base of the footing. Shear resistance of soil above the base of footing is neglected.

6. Method of superposition is valid.
7. Passive pressure force has three components (P_{PC} produced by cohesion, P_{Pq} produced by surcharge and $P_{P\gamma}$ produced by weight of shear zone).
8. Effect of water table is neglected.
9. Footing carries concentric and vertical loads.
10. Footing and ground are horizontal.

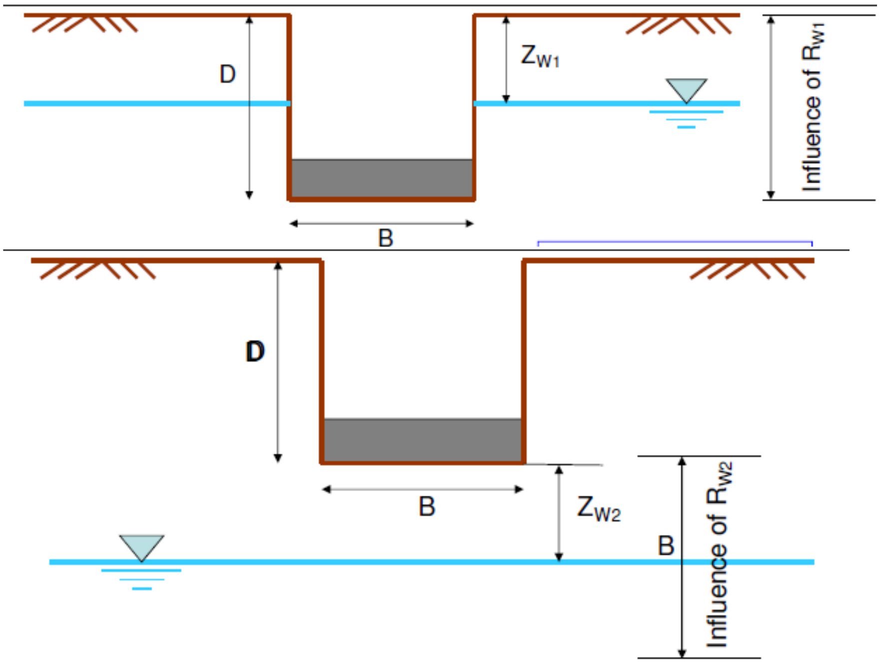
Strip footing, $q_u = C_m N_c + 0.5 B\gamma N_\gamma + \gamma D_f N_q$

Square footing, $q_u = 1.3 C_m N_c + 0.4 B\gamma N_\gamma + \gamma D_f N_q$

Circular footing, $q_u = 1.3 C_m N_c + 0.3 B\gamma N_\gamma + \gamma D_f N_q$

8. (a) Ans:-

The position of ground water has a significant effect on the bearing capacity of soil. Presence of water table at a depth less than the width of the foundation from the foundation bottom will reduce the bearing capacity of the soil. If the ground water is located close to the footing, some changes have to be incorporated in the wedge and surcharge terms of bearing capacity equation. These changes are in the form of water table correction factors R_{w1} & R_{w2}.



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

$$q_f = cN_c + \gamma DN_q R_{w1} + 0.5\gamma BN_\gamma R_{w2}$$

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

8. (b) Ans:-

The procedure for conducting SPT as per IS 2131 guidelines is as follows:
• The borehole is advanced to the required depth and the bottom cleaned.

• The split-spoon sampler, attached to standard drill rods of required length is lowered into the borehole and rested at the bottom.

• The split-spoon sampler is driven into the soil for a distance of 450mm by blows of a drop hammer (monkey) of 65 kg falling vertically and freely from a height of 750 mm. The number of blows required to penetrate every 150 mm is recorded while driving the sampler. The number of blows required for the last 300 mm of penetration is added together and recorded as the N value at that particular depth of the borehole. The number of blows required to effect the first 150mm of penetration, called the seating drive, is disregarded. • The split-spoon sampler is then withdrawn and is detached from the drill rods. The split-barrel is disconnected from the cutting shoe and the coupling. The soil sample collected inside the split barrel is carefully collected so as to preserve the natural moisture content and transported to the laboratory for tests. Sometimes, a thin liner is inserted within the split-barrel so that at the end of the SPT, the liner containing the soil sample is sealed with molten wax at both its ends before it is taken away to the laboratory.

• The SPT is carried out at every 0.75 m vertical intervals in a borehole. This can be increased to 1.50 m if the depth of borehole is large. Due to the presence of boulders or rocks, it may not be possible to drive the sampler to a distance of 450 mm. In such a case, the N value can be recorded for the first 300 mm penetration. • SPT values obtained in the field for sand have to be corrected before they are used in empirical correlations and design charts.

Correction for overburden pressure :- Of two granular soils possessing the same relative density but having different confining pressures, the one with a higher confining pressure gives a higher N value. Since the confining pressure (which is directly proportional to the overburden pressure) increases with depth, the N values at shallow depths are underestimated and the N values at larger depths are overestimated. To allow for this, N values recorded from field tests at different effective overburden pressures are corrected to a standard effective overburden pressure. The corrected N values given by N' = C_n * N;

Cn = Correction factor for overburden pressure.

Correction for dilatancy:- Dilatancy correction is to be applied when N□c obtained after overburden correction, exceeds 15 in saturated fine sands and silts. IS: 2131 – 1981 incorporates the Terzaghi and Peck recommended dilatancy correction (when N□c > 15) using the equation:

Where N_c = final corrected value to be used in design charts.

N'= >15 is an indication of a dense sand. In such a soil, the fast rate of application of shear through the blows of a drop hammer, is likely to induce negative pore water pressure in a saturated fine sand under undrained condition of loading. Consequently, a transient increase in shear resistance will occur, leading to a SPT value higher than the actual one.

9. (a) Ans:-

Classification based on materials or composition:

1. *Timber piles:* Timber piles are made from tree trunks and are well seasoned, straight and free from all defects. Usually available length will be 4 to 6m. Timber piles are used where good bearing stratum is available at a relatively shallow depth.
2. *Concrete piles:* Concrete piles are either precast or cast in-situ. Precast piles are cast and cured at the casting yard and then transported to the site for installation. These piles are adequately reinforced to withstand handling stresses along with working stress. Precast piles are generally used for short lengths. Cast-in-situ piles are constructed by drilling hole in the ground and then filling that hole with freshly prepared concrete after placing the reinforcement.
3. *Steel Piles:* Steel piles are usually of rolled H-sections or thick pipe sections. These piles are used to withstand large impact stresses and where fewer disturbances from driving is desired. These piles are also used to support open excavations and to provide seepage barrier.
4. *Composite piles:* A pile made up of two different materials like concrete and timber or concrete and steel is called composite pile. Composite piles are mainly used where a part of the pile is permanently under water. The part of the pile which will be under water can be made of untreated timber and the other part can be of concrete.

Classification based on the function:

1. *End bearing piles*: Piles which transfer structural load to a hard and relatively incompressible stratum such as rock or dense sand are known as end bearing piles. These piles derive the required bearing capacity from end bearing at tip of the pile.
2. *Friction piles:* These are piles which derive carrying capacity from skin friction or adhesion between the pile surface and surrounding soil.
3. *Combined end bearing and friction piles*: These piles transfer loads by a combination of end bearing at the bottom of the pile and friction along the surface of the pile shaft.

9. (b) Ans:-

Block Failure

$$Q_{u(group)} = C_{ub}N_cA_b + P_bLC_u$$
$$Q_{u(group)} = 4 \times 2.25 \times 9 \times 75$$
$$Q_{u(group)} = 6075\ kN$$

<u>Individual pile Failure</u>

$$Q_u = n\left[CN_cA_p + \alpha CA_s\right]$$

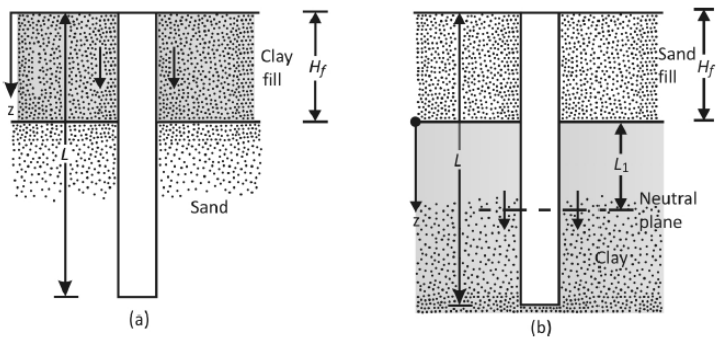
$$Q_u = 9[0 + 0.75 \times 75 \times \pi \times 0.25 \times 9]$$

$$Q_u = 3578.47\ kN$$

Hence the individual pile governs the design.

10. (a) Ans:-

Negative skin friction is a downward drag force exerted on the pile by the soil surrounding it. This action can occur under conditions such as the following:
1. If a fill of clay soil is placed over a granular soil layer into which a pile is driven, the fill will gradually consolidate. This consolidation process will exert a downward drag force on the pile (figure a) during the period of consolidation.
2. If a fill of granular soil is placed over a layer of soft clay, as shown in figure b, it will induce the process of consolidation in the clay layer and thus exert a downward drag on the pile.
3. Lowering of the water table will increase the vertical effective stress on the soil at any depth, which will induce consolidation settlement in clay. If a pile is located in the clay layer, it will be subjected to a downward drag force.



Clay Fill over Granular Soil

The negative (downward) skin stress on the pile is

$$\frac{pK'\gamma'_f H_f^2 \tan\delta}{2}$$

Where, p = perimeter of the pile
H_f = depth of fill/soil which is moving vertically
K = earth pressure coefficient K_o = 1-sinΦ

γ_f = unit weight of the soil
δ = soil-pile friction = 0.5 to 0.7Φ
If the fill is above the water table, the effective unit weight, $\gamma' f$, should be replaced by the moist
unit weight.

Granular Soil Fill over Clay

$Q_{nsf} = p*C*\alpha*H_f$
Where, C = Cohesion in the zone of H_f

Negative Skin Friction (Pile groups)

When a pile group passes through a soft unconsolidated stratum, the magnitude of Q_{nsf} may be
estimated from the following equations and the higher of the values obtained should be used in
design.

Q_{nsf} (block) = n* Q_{nsf}
Q_{nsf}(block) = (C_u*H_f*P_b) + (ɣ*H_f*A_b)
Where, n = no: of piles in the group
P_b = perimeter of the block/group
ɣ = unit weight of the soil within the pile group upto a depth H_f
A_b = area of the block/group.

10. (b) Ans:-

Under reamed piles are bored cast-in-situ concrete piles having one or more number of bulbs formed by enlarging the pile stem.

- These piles are best suited in soils where considerable ground movements occur due to seasonal variations, filled up grounds or in soft soil strata.
- Provision of under reamed bulbs has the advantage of increasing the bearing and uplift capacities. It also provides better anchorage at greater depths.
- Indian Standard IS 2911 (Part III) - 1980 covers the design and construction of under reamed piles having one or more bulbs.
- According to the code the diameter of under reamed bulbs may vary from 2 to 3 times the stem diameter depending upon the feasibility of construction and design requirements.
- The code suggests a spacing of 1.25 to 1.5 times the bulb diameter for the bulbs.
- An angle of 45^0 with horizontal is recommended for all under reamed bulbs.