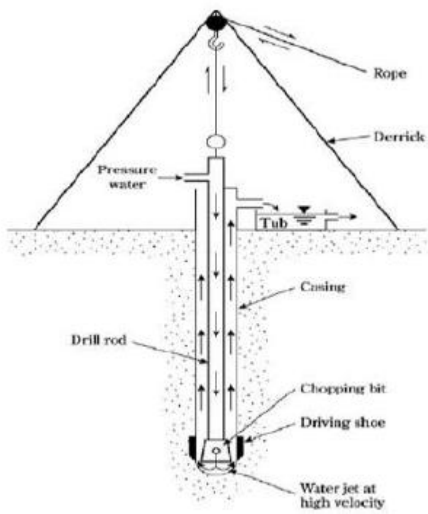
FIFTH SEMESTER B.E.DEGREE EXAMINATION, DEC 2017/JAN 2018

APPLIED GEOTECHNICAL ENGINEERING (15CV53)

1.a) Describe with neat sketch wash boring technique to explore soil. [8 marks]

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.b) The following sizes of sampling tubes are available in market. Out of these which one would you select for obtaining undisturbed soil sample from a base hole. Apply appropriate technique to get best undisturbed sample. [8 marks]

Sample No	I	II	III
Outer dia (mm)	75	110	50
Inner dia	72	107	35
Length (mm)	600	600	600

Ans:-

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

Sample I:- $A_r = (75^2 - 72^2)/ 72^2 *100 = 8.51\% << 20\%$, Samples will be undisturbed. In soft clays A_r must be preferably <10% for really undisturbed samples.

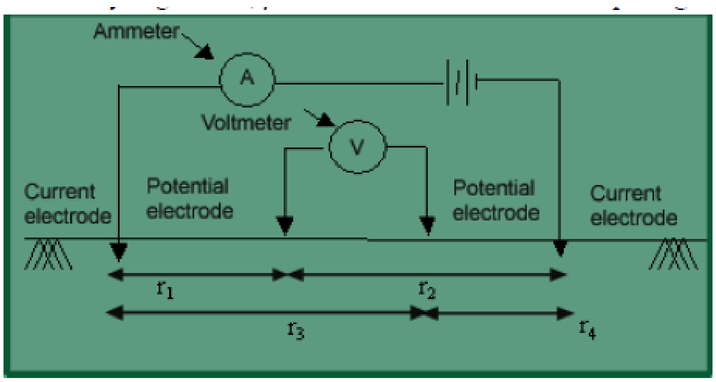
Sample II:- $A_r = (110^2 - 107^2)/ 107^2 *100 = 5.68\% << 20\%$, Samples will be undisturbed. In soft clays A_r must be preferably <10% for really undisturbed samples.

Sample III:- $A_r = (50^2 - 35^2)/ 35^2 *100 = 104.1\% >> 20\%$, Samples will be disturbed in nature.

Sine area ratio of sampling tube II is the least, it can be selected as the best to obtain undisturbed sample from the base hole.

2.a) Explain with neat sketch, electrical resistivity method of soil exploration. [6 marks]

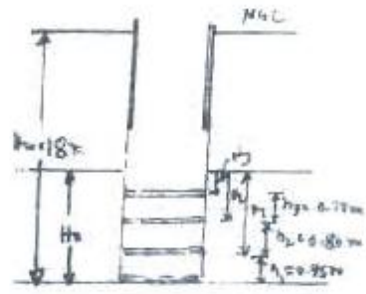
Ans:-



- ✓ Electrical resistivity method is based on the difference in the electrical conductivity or the electrical resistivity of different soils. Electrical resistivity method is based on the difference in the electrical conductivity or the electrical resistivity of different soils.
- ✓ Resistivity is defined as resistance in ohms between the opposite phases of a unit cube of a material.
- ✓ Four metal spikes that serves as electrodes are driven into the ground along a straight line at equal distances.
- ✓ A direct voltage is induced between outer electrodes and potential drop is measured between inner electrodes.
- ✓ Resistivity is given as, $\rho = 2\pi aR$ where a is the spacing between the electrodes.

2.b) Predict the ground water table given the following data: Depth up to which water is bailed out is 18 m, water rise in I day= 0.95 m, II day= 0.86 m, III day = 0.78 m. Use the Hvorslev's method for predicting ground water table. [10 marks]

Ans:- $H_o = h_1^2/(h_1 - h_2) = .95^2 / (.95 - .86) = 10.02$ m



$H_1 = h_2^2/(h_1 - h_2) = .86^2/(.95 - .86) = 8.22$ m

$H_2 = h_3^2/(h_2 - h_3) = .78^2/(.86 - .78) = 7.60$ m

1st day $h_{w1} = H_w - H_o =$ <u>7.98 m</u>

2nd day $h_{w2} = H_w - (h_1 + h_2) - H_1 =$ <u>7.93 m</u>

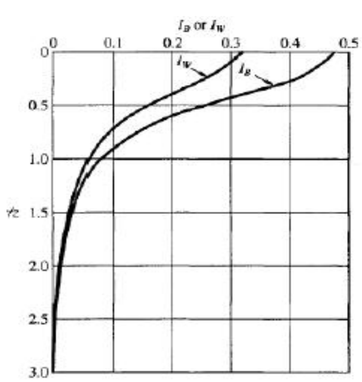
3rd day $h_{w3} = H_w - (h_1 + h_2 + h_3) - H_2 =$ <u>7.89 m</u>

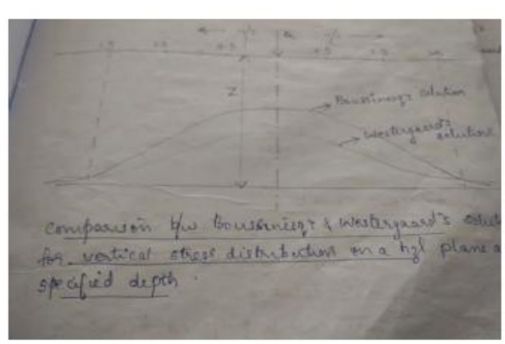
$h_w = (h_{w1} + h_{w2} + h_{w3})/3 =$ <u>7.92 m</u>

<u>3.a)</u> Compare Boussinesq's theory with Westergaard's theory with a logical graph analysis. [8 marks]

Ans:- *<u>Boussinesq's theory:-</u>*
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

<u>Westergaard's theory:-</u>
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) Find intensity of vertical pressure at a point 3m directly below 25 kN point load acting on a horizontal ground surface. What will be the vertical pressure at a point 2m horizontally away from the axis of loading and at the same depth of 3m? Use Boussinesq's equation. [8 marks]

Ans:- Q = 25 kN, z = 3 m.

CASE I:- $\sigma_Z = 0.4775 \frac{Q}{Z^2}$ = 1.326 kN/ m^2

CASE II: Q = 25 kN, z = 3 m, r = 2 m.

$$\sigma_z = I_B \times \frac{Q}{z^2}$$

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

I_B = Boussinesq influence coefficient for vtl stress.

σ_z = 0.53 kN/ m^2.

4.a) Explain components of settlements. [12 marks]

Ans:- Total foundation settlement can be divided into three different components, namely Immediate or elastic settlement, consolidation settlement and secondary or creep settlement.

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 $S_I = \left(\frac{1-\mu^2}{E}\right) qBI_\rho$ Where, 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_f = Influence Factor.

Consolidation Settlement:-It occurs due to the process of consolidation.

- Clay and Organic soil are most prone to consolidation settlement.
- Consolidation is the process of reduction in volume due to expulsion of water under an increased load.

- It is a time related process occurring in saturated soil by draining water from void.
- Consolidation theory is required to predict both rate and magnitude of settlement.
- Since water flows out in any direction, the process is three dimensional.
- 7. But, soil is confined laterally. Hence, vertical one dimensional consolidation theory is acceptable.

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

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

Where, 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 ($= \gamma_{sat} \frac{H}{2}$)

$\Delta\sigma$ = Extra pressure due to the new construction ($= \frac{P}{\left(2\frac{H}{2}+B\right)^2}$)

<u>Secondary Compression:-</u>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.
- This settlement is common in very sensitive clay, organic soils and loose sand with clay binders.

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

Where, 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.

<u>4.b)</u> A reinforced concrete foundation of dimensions 1.8m * 3.6m exerts a uniform pressure of 180 kN/m^2 on a soil mass, with E value 45 MN/m^2. Determine the value of immediate settlement under the foundation. Take μ= 0.3 and I_f =1.0 [4 marks]

Ans:- q = 180 kN/m^2 , B= 1.8 m , μ= 0.3 , I_f =1.0 **,** E = 45 MN/m^2

$$S_i = \left(\frac{1-\mu^2}{E}\right) qBI_\rho$$ = (1-0.3^2/ 45 * 10^3) * 180*1.8*1

= 6.552 mm.

5.a) Compare Coulomb's earth pressure theory over Rankine's earth pressure theory. [6 marks]

Ans:-

Comparison of Coulomb's theory with Rankine's theory

Coulomb's Theory	Rankines theory
① Considers retaining wall & backfill as a system & takes into account the friction b/w wall & the backfill.	① Friction is not considered
② Backfill surface may be plane or curved	② Considers backfill to be a plane surface.
③ Total earth thrust is first obtained & its position & direction of the earth pressure are assumed to be known. Linear variation of pressure with depth is tacitly assumed & direction is automatically obtained from the concept of wall friction	③ Plastic equilibrium insid a semi-infinite soil mass i considered, pressures evaluat a retaining wall is imagine to be interposed later & the location & magnitude of the total earth thrust are establis-hed automatically.

(4) More versatile since (1) any shape of backfill surface can be accounted (2) any break in the wall face or in surface of the fill is accounted.	(4) Not versatile.

(3) Considers effects of stratification of backfill

(4) effects of various kinds of surcharge on earth pressure is considered

(5) effects of cohesion, adhesion & wall friction is considered.

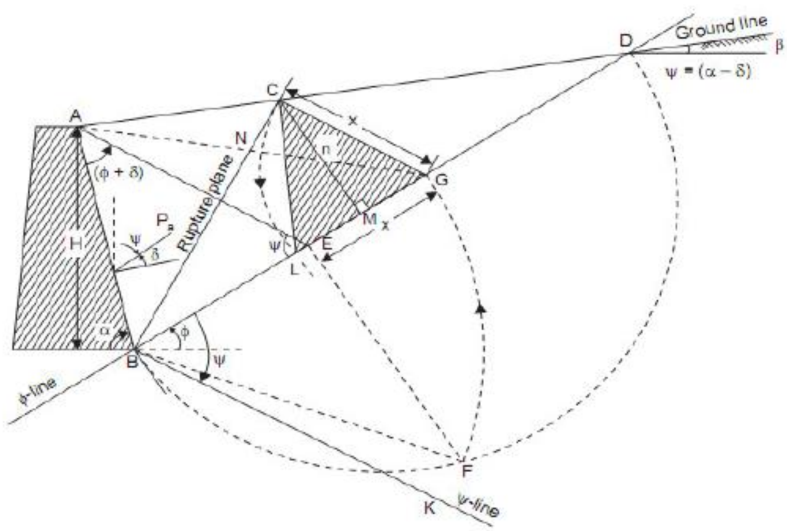
(6) Provides more reliable results from graphical solutions.

5.b) Determine the active earth pressure using Rebhann's graphical method. [10 marks]

Ans:- The steps involved in the graphical method are as follows, with reference to Fig shown

i. Let AB represent the back face of the wall and AD the backfill surface
ii. Draw BD inclined at ϕ with the horizontal from the heel B of the wall to meet the backfill surface in D.
iii. Draw BK inclined at ψ (= α – δ) with BD, which is the ψ-line.

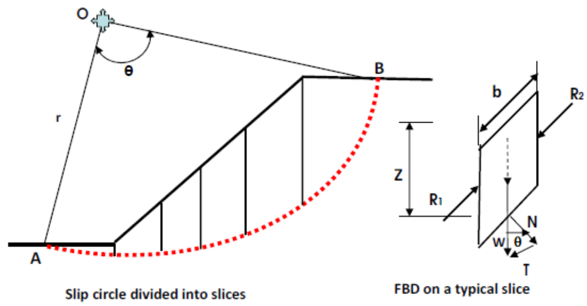
iv. Through A, draw AE parallel to the ψ-line to meet BD in E. (Alternatively, draw AE at (ϕ + δ) with AB to meet BD in E).
v. Describe a semi-circle on BD as diameter.
vi. Erect a perpendicular to BD at E to meet the semi-circle in F.
vii. With B as centre and BF as radius draw an arc to meet BD in G
viii. Through G, draw a parallel to the ψ-line to meet AD in C.
ix. With G as centre and GC as radius draw an arc to cut BD in L; join CL and also draw a perpendicular CM from C on to LG.
x. BC is the required rupture surface.



Poncelet (Rebhann's) graphical construction for active thrust

6.a) Explain the procedure for determination of FOS using method of slices for C-Φ soil. [12 marks]

Ans:- 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 Cosδ, T= W Sinδ

7. The values of N and T are scaled off for each of the slices.

8. The factor of safety is calculated as follows:

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

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

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

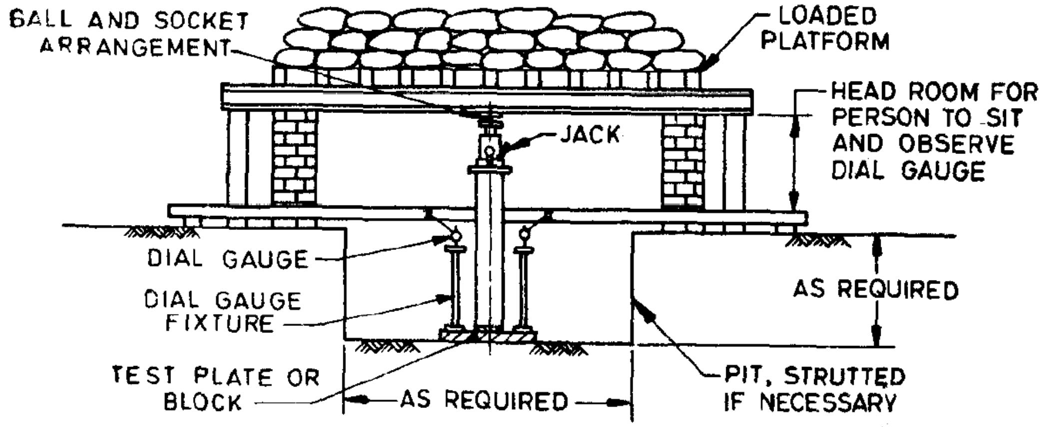
9. Repeat step 2 to 8 by considering various trial slip circles and calculate FS for each of these slip circles. The slip circle with a minimum FS is called critical slip circle.

6.b) An embankment is inclined at an angle of 35◦ and its height is 15 m. The angle of shearing resistance is 15◦ and the cohesion intercept is 40 kN/m2. The unit weight of soil is 18 kN/m^3. Examine the FOS wrt cohesion. Consider Taylor's stability number = 0.06. [4 marks]

Ans:- $F_c = C/ C_m$
$C_m = S_n\ ɣ\ H$ = 0.08 x 18x 15=16.2 KN/m^2
$F_c = C/ C_m$= 40/16.2 = 2.469.

7.a) Determine the bearing capacity of soil by using plate load test as per IS 1888 guidelines. [8 marks]

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 a model footing. Dial gauges, at least 2, of required accuracy (0.002 mm) are placed on plate 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. Red curve indicates the general shear failure & the blue one indicates the local or punching shear failure. The maximum load at which the shear failure occurs gives the ultimate bearing capacity of soil.

7.b) A square footing located at a depth of 1.3m below ground has top carry a safe load of 800 kN. Predict the size of the footing which is safe against applied load, if the desired FOS is 3.0. Assume e= 0.55, degree of saturation = 50%, G = 2.67, C= 8 kN/m^2. Use Terzaghi's analysis for general shear failure. Assume Φ= 30°, N_c= 37.2, N_q= 22.5, N_γ= 19.7 [8 marks]

Ans:- e= 0.55, Sr= 0.5, G = 2.67, C= 8 kN/m^2, Φ= 30°, N_c= 37.2, N_q= 22.5, N_γ= 19.7 , FOS =3, D_f = 1.3 m, γ_w = 10 kN/m^3.

$q_u = 1.3*C*N_c + 0.4*B*\gamma*N_\gamma + \gamma*D_f*N_q$

$\gamma d = (G^* \gamma_w) / (1+e) = (2.67*10)/ (1+0.55) = 17.22$ kN/m^3.

$q_u = 1.3*8*37.2 + 0.4*B*17.22*19.7 + 17.22*1.3*22.5$

$q_u = 890.565 + 135.69*B$

$q_{nu} = q_u - \gamma^* D_f$

$= 890.565 + 135.69*B - 17.22*1.3$

$= 868.179 + 135.69*B$

$q_{ns} = q_{nu} / FOS = (868.179 + 135.69*B)/3$

$= 289.393 + 45.23*B$

$q_s = q_{ns} + \gamma^* D_f$

$= 289.393 + 45.23*B + 17.22*1.3$

$800/ B^2 = 311.779 + 45.23*B$

$\underline{B = 1.455 \text{ m.}}$

8.a) Generalize the assumptions made by Terzaghi's bearing capacity theory for development of bearing capacity equation. [8 marks]

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.

11. Limit equilibrium is reached simultaneously at all points. Complete shear failure is mobilized at all points at the same time.

12. The properties of foundation soil do not change during the shear failure.

8.b) Determine the bearing capacity of soil by using Standard penetration test as per IS 2131 guidelines. [8 marks]

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. The corrected N values given by $N' = C_n * N$;

C_n = Correction factor for overburden pressure.

Correction for dilatancy:- Di1atancy correction is to be applied when obtained after overburden correction, exceeds 15 in saturated fine sands and silts. The corrected equation is N’’ =15+0.5 (N’- 15)

where N’’= final corrected value to be used in design charts.

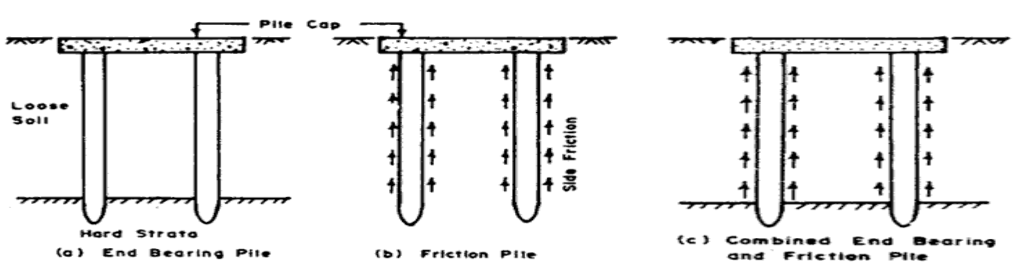
9.a) Classify the various types of piles based on materials and function. [10 marks]
Ans:-

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.



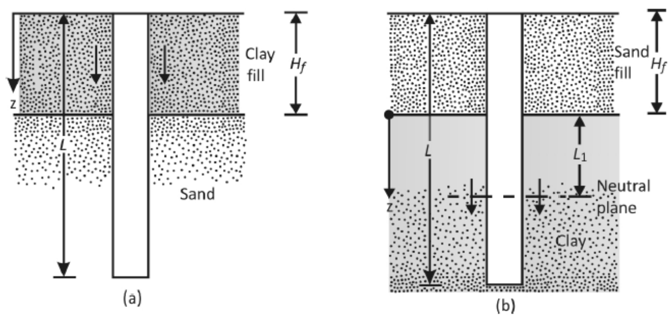
2. *Friction piles:* These are piles which derive carrying capacity from skin friction or adhesion between the pile surface and surrounding soil.

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) Explain negative skin friction in pile foundation. **[6 marks]**

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

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

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 in pile group:- 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) + (γ*H_f*A_b)

Where, n = no: of piles in the group, P_b = perimeter of the block/group, γ = unit weight of the soil within the pile group upto a depth H_f , A_b = area of the block/group.

10.a) Explain with a neat sketch the construction and working of under reamed pile.
[10 marks]

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.

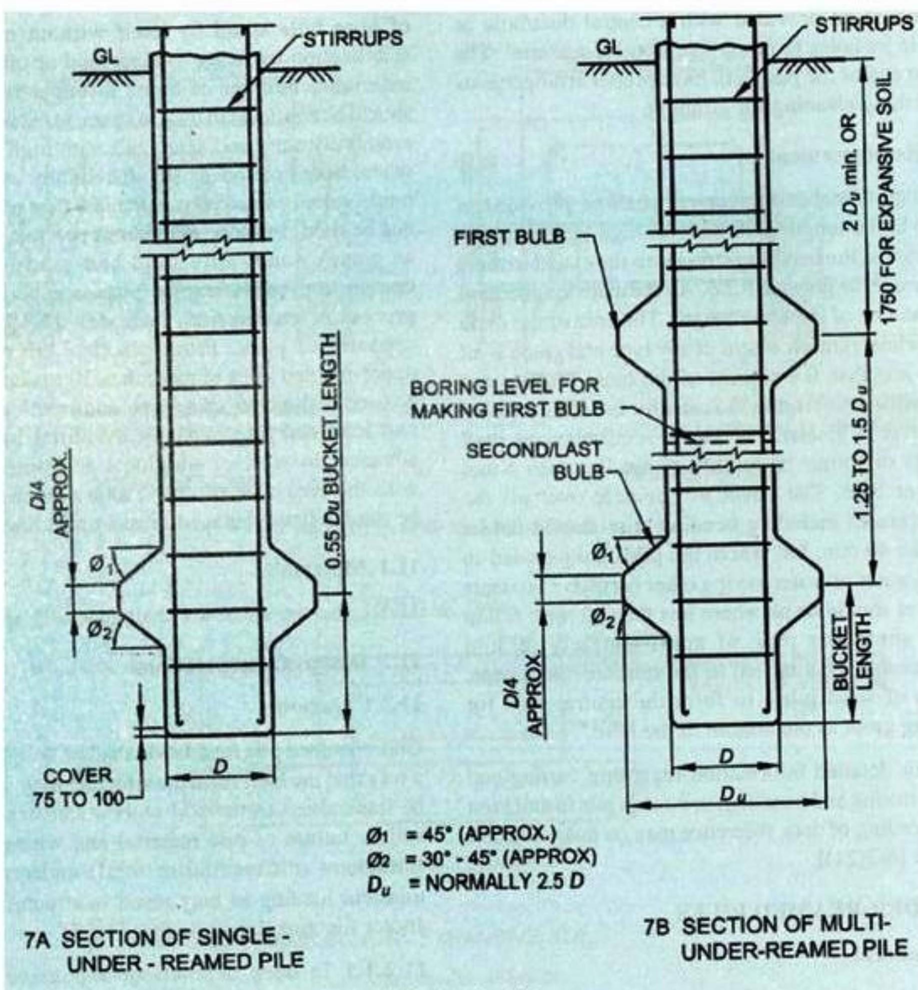
Construction:-

- ✓ Under-reamed piles may be constructed by selecting suitable installation techniques at a given site depending on subsoil strata conditions and type of under-reamed pile and number of bulbs. The ground is leveled and the boring guide is correctly positioned. The boring guide consists of a square frame with 2 sets of flaps and 4 detachable arms having bolting arrangements at corners. Spikes are fixed one in each arm. Soil inside the round collar is taken out. A spiral auger is lowered into the round hole so formed and the flaps are tightened, thus encircling the vertical rod of auger. The auger is then rotated, thus making a bore hole. Boring is done up to required depth and then under-reaming is completed.
- ✓ The under reaming tool attached with a bucket at its end is then lowered vertically down in the bore hole. When pressure is applied on the lowered under reamer assembly, the blades gradually widen or open out and cut the soil which drops in the bucket. When the bucket is full, a pull is applied to the handle and the assembly is taken out for emptying the bucket.
- ✓ In order to achieve proper under-reamed bulb, the depth of bore hole should be checked before starting under-reaming. It should also be checked during under-reaming and any extra soil at the bottom of bore hole removed by auger before reinserting the under-reaming tool.
- ✓ The completion of desired under-reamed bulb is ascertained by (a) the vertical movement of the handle, and (b) when no further soil is cut.
- ✓ In double or multi-under-reamed piles, boring is first completed to the depth required for the first (top) under-ream only and after completing the under-reaming, boring is extended further for the second under ream and the process is repeated.
- ✓ Concreting shall be done as soon as possible after completing the pile bore. For placing concrete in pile bores, a funnel should be used and method of concreting should be such that the entire volume of the pile bore is filled up without the formations of voids and/or mixing of soil and drilling fluid in the concrete. Concreting shall be done by tremie method.
- ✓ 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.

Working :- The load carrying capacity of under-reamed pile depends mainly on the pile dimensions and soil strata. Axial load on a pile is transmitted by point bearing at the toe and the projected area of the bulb(s) and skin friction along the pile stem. Depending upon the nature of soil and pile geometry, in addition to the skin friction on stem, friction can develop on the soil cylinder between the extreme bulbs. In under-reamed compaction piles, the mechanism of load transfer remains the same but soil properties improved by compaction process are considered. In uplift load, point bearing component at toe is absent but unlike other straight shaft piles, point bearing on an anular projection of the bulb is present. Lateral load and moment are sustained by horizontal soil reaction developed along the pile length, which depends on several factors. The design of piles shall be such that it has an adequate factor of safety:

a) as a structural member to transmit the imposed loads, and

b) against failure of strata due to reaching ultimate strength. Further it should ensure that the desired limit of settlement is not exceeded.



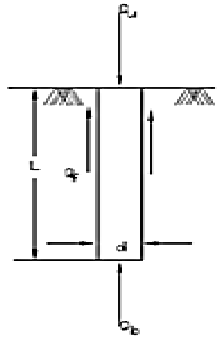
7A SECTION OF SINGLE - UNDER - REAMED PILE

7B SECTION OF MULTI-UNDER-REAMED PILE

All dimensions in millimetres.

10.b Justify with an neat sketch, how static formula summarize the load transfer mechanism in pile foundations. [6 marks]

Ans:- The static formulae for ultimate load carrying capacity of pile based on soil properties and pile geometry.



(a)

Piles in granular soils: Point bearing in granular soil, $q_{nu} = \bar{\sigma} N_q$ Where σ is the effective overburden pressure at the tip of the pile = ɣ*L; L is the length of the embedment of the pile.

Unit skin friction, $f_s = \sigma_h \tan \delta = K \bar{\sigma} \tan \delta$ Where K is the lateral earth pressure coefficient and δ is the angle of internal friction between the pile and the soil.

Ultimate skin friction resistance Qs $= K \bar{\sigma}_{av} \tan \delta$

The ultimate load Q_u is given by *Q*u = End bearing resistance *Q*p+ Skin resistance Qs

$= (q*N_q*A_p) + (k*\sigma_v*A_s*\tan\delta)$

Where, A_p = Cross section area of pile, N_q = Bearing capacity factor, σ_v= Effective overburden pressure ,k= Co-efficient of earth pressure, σ_v= Effective over burden pressure at middle of corresponding layer, δ = Angle of wall friction usually taken as ¾ ø of soil, A_s = Surface area of pile.

Table-5.1 Values of K and δ

Pile material	δ	Values of K	
		Loose sand	Dense sand
Steel	20	0.5	1.0
Concrete	0.75 Φ	1.0	2.0
Timber	0.67 Φ	1.5	4.0

Piles in cohesive soils :- The ultimate bearing Q_u of piles in cohesive soils is given by the following formula

Q_u = End bearing resistance Q_p + Skin resistance Qs

$= (C_p*N_c*A_p) + (\alpha*C*A_s)$

Where, N_c = Bearing capacity factor in clays which is taken as 9

C_p = Average cohesion at pile toe.

α = Adhesion factor.
C = Average cohesion along the shaft length.
A_s = Surface area of pile.