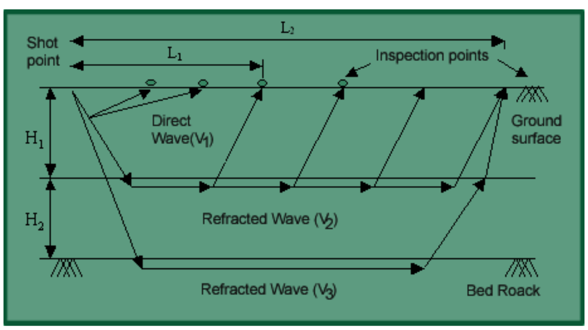
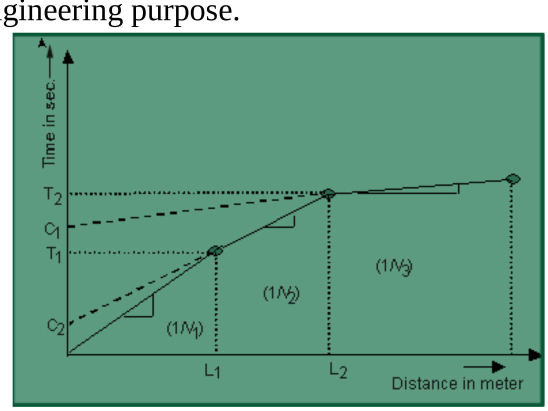
APPLIED GEOTECHNICAL ENGINEERING (15CV53)
SCHEME & SOLUTION IAT-1

1.(a) Explain seismic refraction method with a neat sketch.

Ans:- ***Explanation- 4marks, Fig + graph+ formula – 3marks.***

- ✓ Based on the fact that seismic waves have different velocities in different types of soils (or rock) and besides the wave refract when they cross boundaries between different types of soils.
- ✓ Shock waves are created into the soil by exploding small charges or by striking a plate on the soil with a hammer. These waves are classified as direct, reflected and refracted waves.
- ✓ Radiating shock waves are picked up by geophones, where the time of travel gets recorded.
- ✓ Either a number of geophones are arranged along a line or shock producing device is moved away from the geophone.
- ✓ The direct wave travel in approximately straight line from the source of impulse. The reflected and refracted wave undergoes a change in direction when they encounter a boundary separating media of different seismic velocities.
- ✓ Results are plotted as a graph shown in figure below.
- ✓ Suited for the shallow explorations for civil engineering purpose.





- ✓
- ✓ **Seismic refraction method** **Graph of Time vs Distance**

V1= L1/T1, V1 = velocity of direct waves.

Thickness of first layer H1= C2*V1/2 and H2 = (C1-C2)*V2/2

1.(b) Explain the different types of soil samples.

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. (***Explanation- 1 mark).***

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. (***Explanation- 1.5 marks).***

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. (***Explanation- 1.5 marks).***

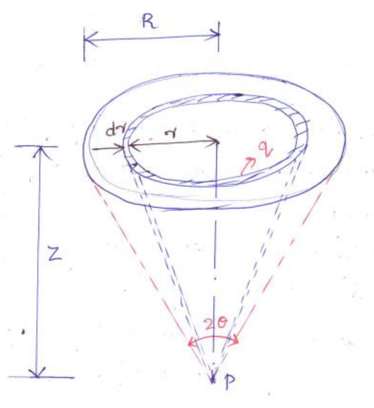
1.(c) Establish the ground water level by Hvorslev's method, given the following data: depth up to which water table is bailed out =15m, water rise on 1st day=0.80m, water rise on 2nd day=0.70m, water ries on 3rd day=0.60m

Ans:-

$H_o = h_1^2/(h_1 – h_2) = .0.8^2 / (.80 – .70) = 6.4$ m – ***1mark***
$H_1= h_2^2/(h_1 – h_2) = .70^2 / (.80 – .70) = 4.9$ m – ***1mark***
$H_2 = h_3^2/(h_2 – h_3) = .60^2 / (.70– .60) = 3.60$ m – ***1mark***
1st day $h_{w1} = H_w – H_o$ = $\underline{8.6\text{ m}}$ –- ***0.5 mark***
2nd day $h_{w2} = H_w – (h_1 + h_2) - H_1$ = $\underline{8.6\text{ m}}$ – ***0.5 mark***
3rd day $h_{w3} = H_w – (h_1 + h_2 + h_3) - H_2$ = $\underline{9.3\text{ m}}$ – ***1mark***
$h_w = (h_{w1} + h_{w2} + h_{w3})/3$ = $\underline{8.83\text{ m}}$ – ***1mark***

2.(a) Derive the expression for vertical stress under a uniformly loaded circular area by Boussinesq's theory.

Ans:- ***Figure- 2 marks, Derivation – 5 marks.***



Let 'q' per unit area = intensity of load &

R be the radius of loaded area.

Boussinesq's solution can be used to determine σ_z.

Consider an elementary ring of radius r & width dr, in Load = $q \times (2\pi r) dr$.

The Load acts at a constant radial distance r from point P.

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

vertical stress due to entire load is given by

$$\sigma_z = \frac{3q}{z^2} \times \int_0^R \frac{r\,dr \times (z^2)^{5/2}}{(r^2+z^2)^{5/2}}$$

$$= 3q z^3 \int_0^R \frac{r\,dr}{(r^2+z^2)^{5/2}}$$

$$\sigma_z = 3q z^3 \int_{z^2}^{(R^2+z^2)} \frac{du}{2u^{5/2}}$$

Let $r^2 + z^2 = u$.

$\therefore 2r\,dr = du$

when $r = 0$; $u = z^2$

when $r = R$; $u = R^2 + z^2$.

$$\sigma_z = \frac{3q z^3}{2} \left[\frac{1}{u^{3/2}}\right]_{z^2}^{R^2+z^2} \times \left(-\frac{2}{3}\right)$$

$$= -q z^3 \left[\frac{1}{(R^2+z^2)^{3/2}} - \frac{1}{(z^2)^{3/2}}\right]$$

$$= +q z^3 \left[\frac{1}{z^3} - \frac{1}{(R^2+z^2)^{3/2}} \right]$$

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

or $\sigma_z = I_c \cdot q$

where $I_c = \left[1 - \left\{\frac{1}{1+(\frac{R}{z})^2}\right\}^{3/2}\right]$

(influence coefficient of o^{lar} area)

Let 2θ be the angle subtended at point P by load. then $\tan\theta = R/z$

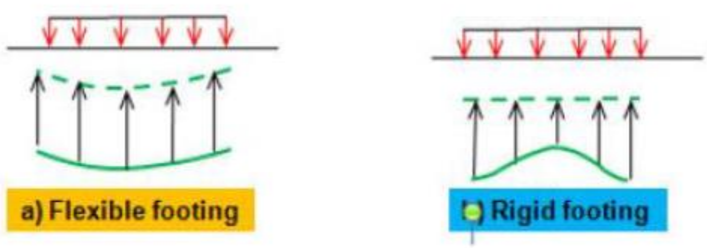
$$I_c = \left[1 - \left\{\frac{1}{1+\tan^2\theta}\right\}^{3/2}\right]$$

$$I_c = 1-(\cos^2\theta)^{3/2} = 1-\cos^3\theta$$

2.(b) Explain with a neat sketch, the contact pressure distribution in clayey soil.

Ans:- ***Figure- 2 marks, Explanation – 3 marks***

<u>In clayey soils:-</u>



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.

2.(c) 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:- ***Boussinesq's analysis- 1 + 1.5 marks, Westergaard's analysis- 1 + 1.5 marks.***

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

Boussinesq's analysis –

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

$= \underline{9.55 \text{ kN/m}^2}$

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

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

Westergaards

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

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

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

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

3.(a) Briefly explain the components of settlement.

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. **(*Explanation with formula – 2 marks)***

<u>Consolidation Settlement:-</u>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 ($= \frac{P}{\left(2\frac{H}{2}+B\right)^2}$)(***Explanation with formula – 2 marks)***

<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. **(*Explanation with formula – 2 marks)***

3.(b) A circular footing 2 m diameter is resting on the ground surface. The subsoil consists of fine sand of 6m depth underlain by 4m thick clay layer. The ground water table is 1m below ground level. The unit weights of sand above and below water table are 17.6 kN/m^3 and 20 kN/m^3 respectively. The properties of clay are w=40%, liquid limit=45% and G=2.72. Estimate the probable settlement if the footing transfers a uniformly distributed load of 300 kPa.

Ans:- H= 4m, $\Delta\sigma$ = 300 kPa, e = w*G/Sr = 1.088 – ***1 mark***
C_c = 0.009(45-10) = 0.315 ***1 mark***
γ_{sub}(clay) = (2.72-1)/(1+1.088)*10 = 8.24 kN/m^3 ***0.5 mark***
γ_{sub}(sand) = 20-10 = 10 kN/m^3 ***0.5 mark***
σ = (17.6*1) + (10*5) + (8.24*2) = 84.08 kPa ***1 mark***

$$Sc = \left\{\frac{C_c}{1+e}\right\} * H * \log_{10}\left(\frac{\sigma + \Delta\sigma}{\sigma}\right)$$

$$Sc = \left\{\frac{0.315}{1+1.088}\right\} * 4 * \log_{10}\left(\frac{84.08 + 300}{84.08}\right)$$

= 0.398m. ***1 mark***

3.(c) What are the different methods available for dewatering ? Explain dewatering by well point system.

Ans:- ***Explanation- 3 marks, figure- 2 marks.***

A well point system consists of a number of well points spaced along a trench or around an excavation site.

- ✓ These well points in turn are all connected to a common header that are attached to one or more well point pumps.
- ✓ Well point assemblies-are made up of a well point, screen, riser pipe, and flexible hose swinger and joint with tuning.
- ✓ These are generally installed by jetting.
- ✓ They provide for entry of water into the system by creation of a partial vacuum.
- ✓ The water is then pumped off through the header pipe.

Advantages of well point system

- ✓ Installation is very rapid
- ✓ Water is filtered and carries little or no soil particles.

Limitations of well point system

- ✓ If the ground is consisting mainly of large gravel, stiff clay or soil containing cobbles or boulders it is not possible to install well points.