Solution - Internal Assessment Test II – December 2021

1 (a) What is a flownet? State the characteristics and uses of flownets. [06]

Definition - 1
Characteristics – 3
Uses - 2

Graphical form of solutions to Laplace equation for two-dimensional seepage can be presented as flow nets. Two orthogonal sets of curves form a flow net:

- Equipotential lines connecting points of equal total head h
- Flow lines indicating the direction of seepage down a hydraulic gradient

Flow Lines are the paths which water particle follow in the course of seepage. Water flows from the point of higher head to low head.

Equipotential lines are the lines formed by joining the points of same head or potential on the flow lines.

Properties of Flow net:

- Flow lines and equal potential lines intersect each other at 90 degrees.
- The areas bounded by the flow lines and equal potential lines form approximate squares.
- Flow nets must satisfy the boundary conditions of flow field.
- Quantity of water flowing through each flow channel is the same.
- The potential drop in any two consecutive equal potential lines is same/constant.
- Flow lines and equal potential lines are smooth curves.
- Flow lines do show refraction at the interface between two soils having different coefficient of permeability.

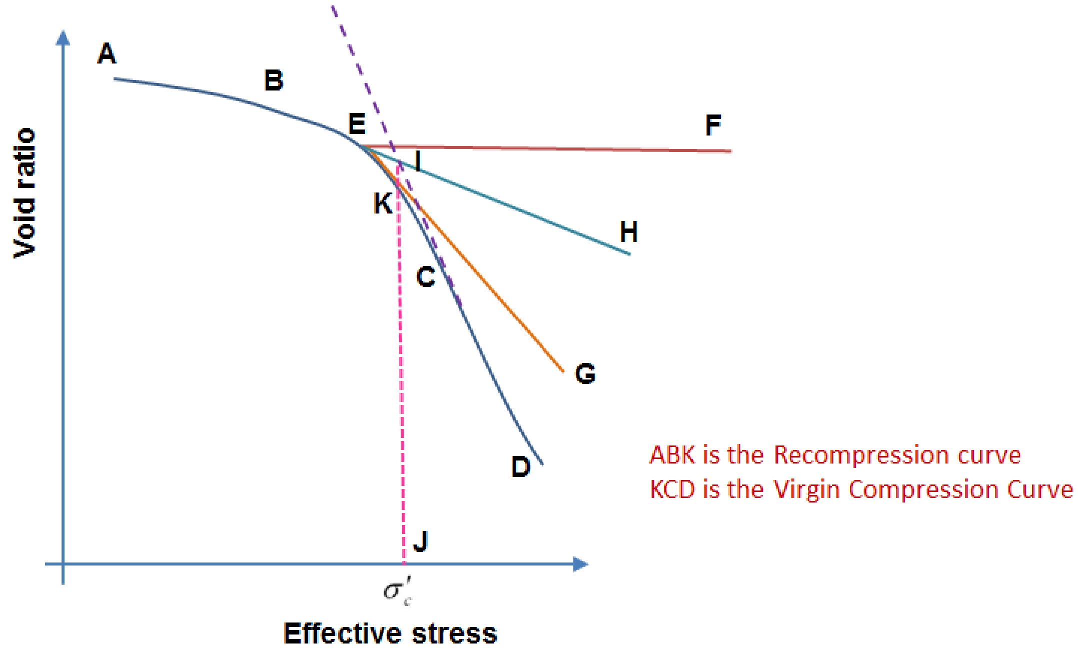
Uses of flownets:

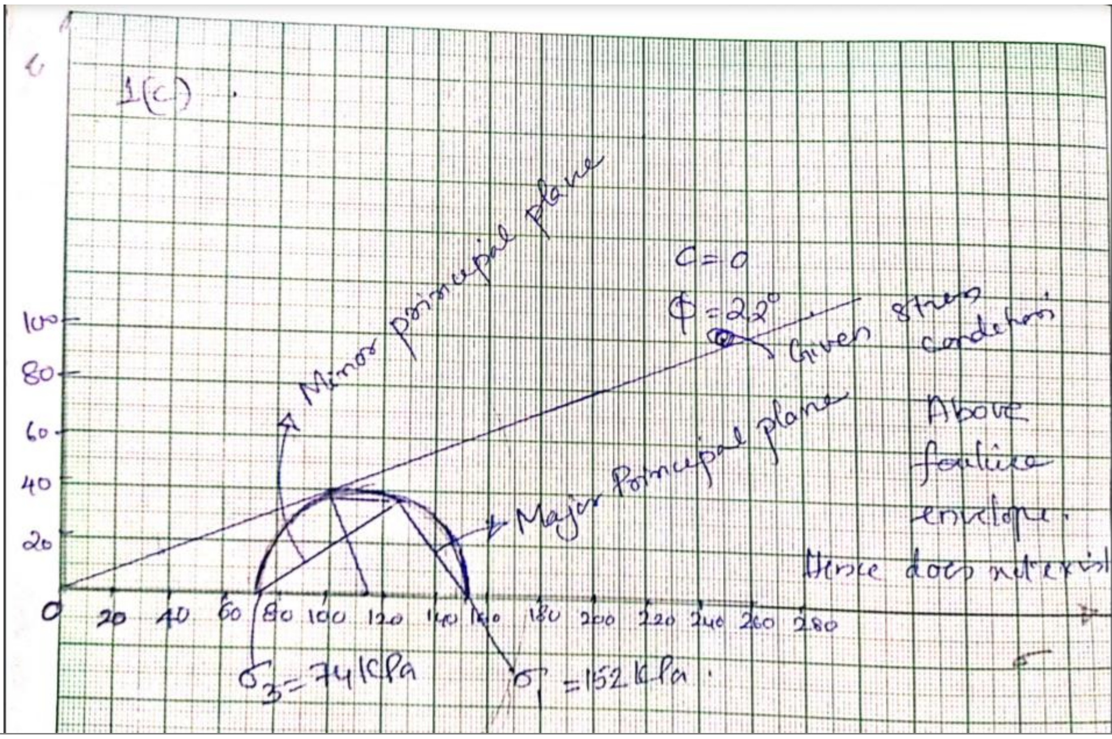
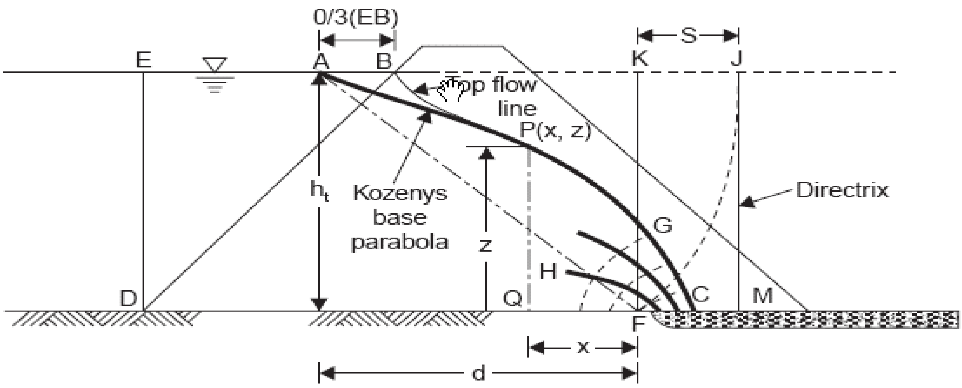
1. <u>Determination of seepage</u>
   Knowing the number of flowchannels and equipotential drops, seepage can be estimated as
   $$q = kh\frac{N_f}{N_d}$$
2. Determination of hydrostatic pressure
   The hydrostatic pressure at any point within the soil mass is given as
   $u = h_w . \gamma_w$
   $Total\ head\ h = piezometric\ head\ (h_w) + datum\ head\ (z)$
   To plot lines of equal pressure:
   When h_w =20%h and h_w = 30% h
   z = 30 – 20 = 10% h, like this we can locate z
3. Determination of seepage pressure
   Hydraulic potential h at any point located after n equipotential drops , h = H – nΔh
   Seepage pressure = h. γ_w
4. Determination of exit gradient
   The hydraulic gradient at the downstream end is given as $i_c = \Delta h/l$

(b) Define preconsolidation pressure. Explain with neat sketch, determination of preconsolidation pressure by Casagrande's method. [06]

Explanation – 4
Sketch - 2

The maximum pressure to which the soil has been subjected to it, in the past is called as preconsolidation pressure. Casagrande's method for estimating preconsoldiation pressure is as explained below:

	1. Plot void ratio vs effective stress variation and mark it as ABCD. 2. Choose by eye the point of maximum curvature on the consolidation curve Say E. 3. Draw a horizontal line from this point, line EF. 4. Draw a line tangent to the curve at the point E, line EG. 5. Bisect the angle made from the horizontal line EF and the tangent line EG. Name the bisector as EH. 6. Extend the "straight portion" of the virgin compression curve (high effective stress, low void ratio: almost vertical on the right of the graph) up to the bisector line DG so as to intersect at I. 7. Drop vertical IJ and the abscissa of IJ indicate pre consolidation pressure. 8. Vertical IJ intersect e-log $\bar{\sigma}$ curve at K, Curve ABK indicates recompression curve and curve KCD indicate virgin compression curve.  	
	(c) The stresses on a failure plane in a drained test on a cohesionless soil are as under: Normal stress (σ) = 100 kPa; Shear stress (τ) = 40 kPa Determine the angle of shearing resistance and the angle which the failure plane makes with the major principal plane. Also, find the major and minor principal stresses. Also state if failure occur in a plane within the soil mass when shear stress is 100 kPa and normal stress is 250 kPa.	[08]
	Graph - 2 Determination of principal stresses and principal planes - 4 State of stress - 2	

		
2	(a) Explain with a neat sketch the method of locating the phreatic line in a homogenous dam with horizontal filter.	[06]
	Explanation – 4 Sketch – 2	
	Graphical form of solutions to Laplace equation for two-dimensional seepage can be presented as flow nets. Two orthogonal sets of curves form a flow net: • Equipotential lines connecting points of equal total head h • Flow lines indicating the direction of seepage down a hydraulic gradient Flow Lines are the paths which water particle follow in the course of seepage. Water flows from the point of higher head to low head. The top flow line is also known as the 'phreatic line', as the pressure is atmospheric on this line. Thus, the pressures in the dam section below the phreatic line are positive hydrostatic pressures.  1. Locate the point A, using BA = 0.3 (BE). A will be the starting point of the Kozeny parabola. 2. With A as centre and AF as radius, draw an arc to cut the water surface (extended) in J. The vertical through J is the directrix. Let this meet the bottom surface of the dam in M. 3. The vertex C of the parabola is located midway between F and M.	

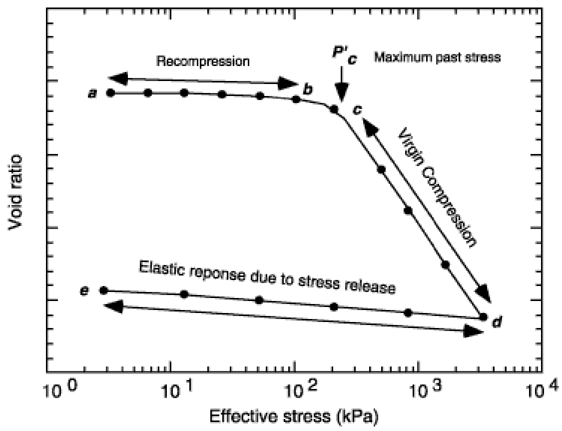
4. For locating the intermediate points on the parabola the principle that it must be equidistant from the focus and the directrix will be used. For example, at any distance x from F, draw a vertical and measure QM. With F as center and QM as radius, draw an arc to cut the vertical through Q in P, which is the required point on the parabola.

Join all such points to get the base parabola. The portion of the top flow line from B is sketched in such that it starts perpendicular to BD, which is the boundary equipotential and meets the remaining part of the parabola tangentially without any kink. The base parabola meets the filter perpendicularly at the vertex C.

(b) Briefly explain Normally Consolidated (NC), Under Consolidated (UC) and Over Consolidated soils (OC). [06]

Definition of each – 4.5
Indication in figure – 1.5

A soil which is subjected to a pressure for the first time in its life time is called as normally consolidated clay. Such clays exhibit high compression which is indicated by virgin compression curve.
A soil which is subjected to a pressure greater than the existing pressure is called as overconsolidated clay. Such clays exhibit less settlement as indicated by recompression curve.



The preconsolidation stress, is defined to be the maximum effective stress experienced by the soil. If the current effective stress, s', is equal (note that it cannot be greater than) to the preconsolidation stress, then the deposit is said to be normally consolidated (NC). If the current effective stress is less than the preconsolidation stress, then the soil is said to be over-consolidated (OC).
A soil which has not reached equilibrium under the applied pressure itself is called as underconsoldiated clay. Eg. Landfills.

Normally and
Over-Consolidated Soils

$\sigma'_{zo} = \sigma'_c$ ..... Normally consolidated

$\sigma'_{zo} < \sigma'_c$ ..... Over consolidated

$\sigma'_{zo} > \sigma'_c$ ..... Under consolidated

Where σ'_{z0} is the existing pressure and σ'_c is the preconsolidation pressure.

(c) A sand deposit is 12 m thick and overlies a bed of soft clay. The ground water table is 3 m below the ground surface. If the sand above the ground water table has a degree of saturation of 42%, plot the diagram showing the variation of total stress, pore water pressure and effective stress. The void ratio of sand is 0.65. Take G = 2.65. [08]

	Determine the increase in effective stress if the water table is lowered by 5 m further (8 m from top). Assume that soil above water table has a degree of saturation of 42%.	
	Stress calculation +figure -6 Increase in stress - 2	

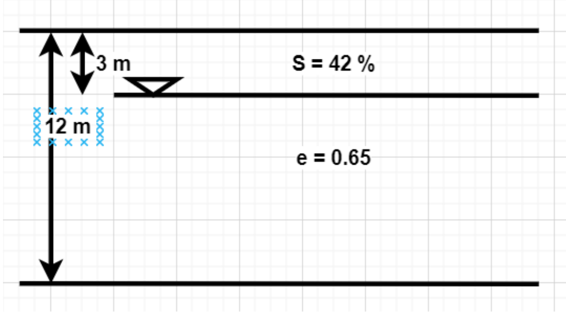
$$\gamma_{sat} = \frac{\gamma_w(G+eS)}{1+e}$$

$$\gamma_{sat} = \frac{10(2.65+0.65)}{1+0.65}$$

$$\gamma_{sat} = 20\ kN/m^3$$

$$\gamma = \frac{10(2.65 + 0.65 \times 0.42)}{1 + 0.65}$$

$$\gamma = 17.72\ kN/m^3$$



Depth below ground surface	σ, kPa	u, kPa	σ', kPa
Z=0	0	0	0
Z=3m	=17.72×3=53.16	0	=53.16
Z=12m	= 53.16 + 20×9 = 233.16 kPa	90	143.16

Effective stress for new WT = (17.72×8 +20×4) – (10×4) = 181.76 kPa
Increase in effective stress = 181.76 – 143.16 = 38.6 kPa

3	(a) Explain Mohr Coulomb failure theory of soil with neat sketches.	[05]
	Mohr Envelope - 2 Mohr Coulomb Envelope - 2 Sketches - 1	

Shear strength of a soil represents the resistance to shear stresses. According to Mohr, failure is caused by a critical combination of normal and shear stresses as represented by equation (1).

Or $\tau = f(\sigma)$ (1)

Graphically equation (1) will be curved in shape as seen in Fig. 5.1. At failure, the Mohr failure envelope will be tangential to the Mohr's circle.

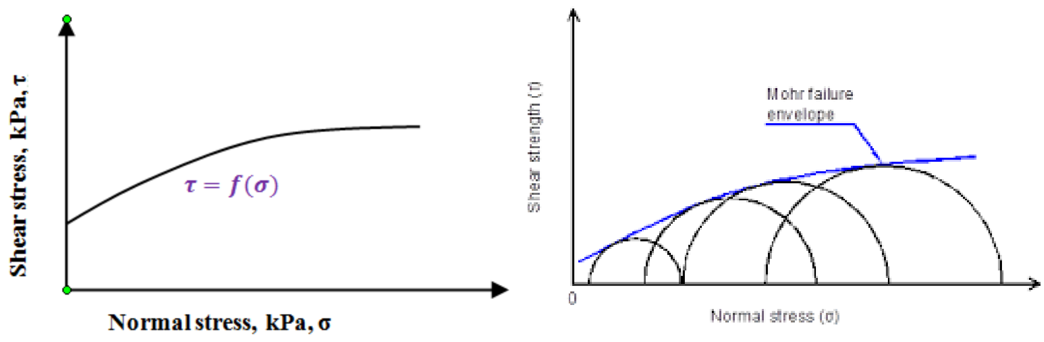


Figure 5.1. Mohr's failure envelope

Coulomb modified Mohr's theory by stating that shear strength of soil is dependent on two parameters: cohesion between the soil particles and the friction between the particles. Accordingly Equation (1) was modified and the equation for modified failure envelope is given by Equation (2). Mohr's modified failure envelope is given in Fig.5.2

$\tau = c + \sigma\, tan\varphi$ (2)

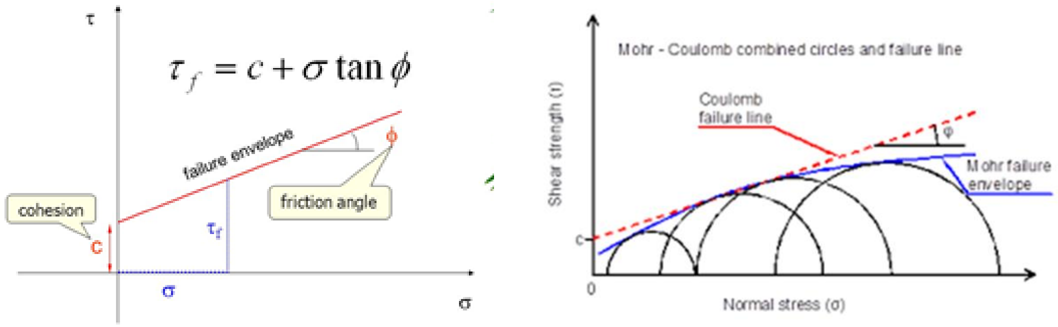


Figure 5.2. Mohr's failure envelope

(b) The porosity of a certain sample of sand was 52% in the loose state and 37% in the dense state. The specific gravity is 2.7. Estimate the critical hydraulic gradients in loose and dense states. [05]

Calculation of e – 2
Formula and calculation -3

$$n = \frac{e}{1+e}$$

For loose state, e = 1.08
i = (G-1)/(1+e) = 0.817
For dense state, e = 0.59
i = (G-1)/(1+0.59) = 1.07

Signature of CI Signature of CCI Signature of HoD