6. SEEPAGE ANALYSIS

SEEPAGE PRESSURE AND SEEPAGE FORCE

Seepage pressure is exerted by the water on the soil due to friction drag. This drag force/seepage force always acts in the direction of flow.

The seepage pressure is given by

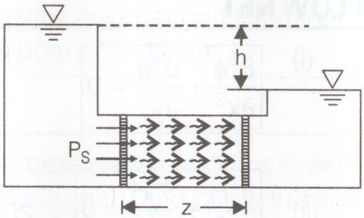
$$P_S = h\gamma_\omega$$

where, P_s = Seepage pressure

γ_ω = 9.81 kN/m³.

Here, h = head loss

and z = length



(ii) $F_s = hA\gamma_\omega$ where, F_s = Seepage force.

(iii) $f_s = i\gamma_\omega$ where, f_s = Seepage force per unit volume.

$i = h/z$ where, i = Hydraulic gradient.

> **NOTE:** P_s, F_s and f_s acts in the same direction i.e., in the direction of flow.

EFFECTIVE STRESSES

The effective stress is equal to the total stress minus the pore water pressure.

(i) Net effective vertical stress = $\bar{\sigma} \pm P_s$

sign convn → +ve when flow is downward.

→ −ve when flow is upward.

(ii) For Vertically Upward Flow

$$\text{Net effective vertical stress} = \bar{\sigma} - h\gamma_w$$

where, $\bar{\sigma} = \gamma_{sub} \cdot Z$ and $\gamma_{sub} = \left(\frac{G-1}{1+e}\right)\gamma_w$

QUICK SAND CONDITION

It is a condition but not the type of sand in which the net effective vertical stress becomes zero, when seepage occurs vertically up through the sands/cohesionless soils.

Net effective vertical stress = 0

$i_c = \dfrac{G-1}{1+e}$ where, i_c = Critical hydraulic gradient.

$2.65 \le G \le 2.70$

$0.65 \le e \le 0.70$

- To Avoid Floating Condition $i < i_c$ and $F \cdot O \cdot S = \dfrac{i_c}{i} > 1$

LAPLACE EQUATION OF TWO DIMENSIONAL FLOW AND FLOW NET

(i) $\dfrac{\partial^2 \phi}{\partial x^2} + \dfrac{\partial^2 \phi}{\partial y^2} = 0$ where, ϕ = Potential function = kH

H = Total head

and k = Coefficient of permeability

(ii) $\dfrac{\partial^2 H}{\partial x^2} + \dfrac{\partial^2 H}{\partial Y^2} = 0$ ... 2D Laplace equation for Homogeneous soil.

where, $\phi = k_x H$ and $\phi = k_y \cdot H$ For Isotropic soil, $k_x = k_y$

SEEPAGE DISCHARGE (q)

$q = kh \cdot \dfrac{N_f}{N_d}$ where, h = hydraulic head or head difference between upstream and downstream level or head loss through the soil.

- $\text{Shape factor} = \dfrac{N_f}{N_d}$
- $N_f = N_\psi - 1$ where, N_f = Total number of flow channels

  N_ψ = Total number of flow lines.
- $N_d = N_\phi - 1$ where, N_d = Total number equipotential drops.

  N_ϕ = Total number equipotential lines.
- Hydrostatic pressure = $U = h_w \gamma_w$ where, U = Pore pressure

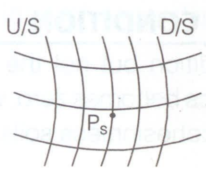
  h_w = Pressure head

h_w = Hydrostatic head − Potential head

- **Seepage Pressure**

$P_s = h' \gamma_w$

where, $h' = h - \left(\dfrac{2h}{N_d}\right)$



- Exit gradient,

$i_e = \dfrac{h}{b.N_d}$ where, size of exit flow field is b × b.

and $\Delta h = \dfrac{h}{N_d}$ is equipotential drop.

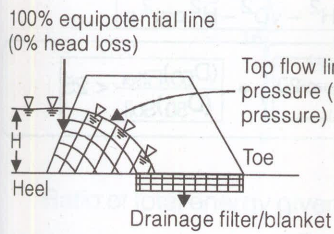
Remember

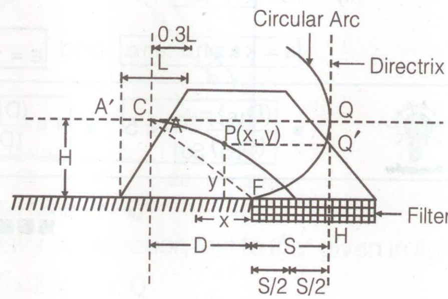
- Flow net will remain same if U/S and D/S water levels are interchanged and direction of flow is reversed provided the flow boundary is not changed.
- Flow net is changed if boundary conditions are changed it means flow net is unique for a given set of boundary conditions.

PHREATIC LINE

It is top flow line which follows the path of base parabola. It is a stream line. The pressure on this line is atmospheric (zero) and below this line pressure is hydrostatic.

(a) Phreatic Line with Filter





Phreatic line (Top flow line).

↓

Follows the path of base parabola

CF = Radius of circular arc = $\sqrt{D^2 + H^2}$

C = Entry point of base parabola

F = Junction of permeable and impermeable surface

S = Distance between focus and directrix

= Focal length.

FH = S

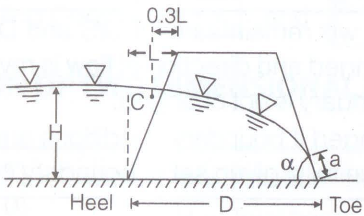
(i) $q = ks$ where, q = Discharge through unit length of dam.

(ii) $S = \sqrt{D^2 + H^2} - D$

(iii) $K = \sqrt{k_x k_y}$ → For 2D

$K = (k_x k_y k_z)^{1/3}$ → For 3D

(b) Phreatic Line without Filter



(i) For $\alpha < 30°$

$q = k a \sin^2 \alpha$ and $a = \dfrac{D}{\cos\alpha} - \sqrt{\dfrac{D^2}{\cos^2\alpha} - \dfrac{H^2}{\sin^2\alpha}}$

(ii) For $\alpha > 30°$

$q = k a \sin\alpha \tan\alpha$ and $a = \sqrt{D^2 + H^2} - \sqrt{D^2 - H^2 \cot^2 \alpha}$

Remember

- $\dfrac{(D_{15})\text{ Filter}}{(D_{85})\text{ Soil}} < 5$; • $4 < \dfrac{(D_{15})_{\text{Filter}}}{(D_{15})_{\text{Soil}}} < 20$; • $\dfrac{(D_{50})_{\text{Filter}}}{(D_{50})_{\text{Soil}}} < 25$

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