SOIL MECHANICS (CE-505)

Lecture 10:

TWO Dimensional Flow – Part2

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FLOWNETS IN ANISOTROPIC SOILS

- Laplace Equation

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0$$

- In nature most soils exhibit some degree of anisotropy.
- To account for soil anisotropy with respect to hydraulic conductivity, the flow net constructions must be modified.
- The differential equation of continuity for a two-dimensional flow is

$$k_x \frac{\partial^2 h}{\partial x^2} + k_Y \frac{\partial^2 h}{\partial y^2} = 0$$

$$\frac{\partial^2 h}{(k_y/k_x)\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0$$

- $x' = \sqrt{k_y/k_x}\, x$

$$\frac{\partial^2 h}{\partial x'^2} + \frac{\partial^2 h}{\partial y^2} = 0$$

Now above equation is in a form similar to that for isotropic with *x* replaced by *x'*, which is the new transformed coordinate.

FLOWNETS IN ANISOTROPIC SOILS

1. Adopt a vertical scale (that is, *y* axis) for drawing the cross section.
2. Adopt a horizontal scale (that is, *x* axis) such that

   horizontal scale = $\sqrt{k_y/k_x}$ × *vertical scale.*

3. With scales adopted as in Steps 1 and 2, plot the vertical section through the permeable layer parallel to the direction of flow.
4. Draw the flow net for the permeable layer on the section obtained from Step 3, with flow lines intersecting equipotential lines at right angles and the elements as approximate squares.

FLOWNETS IN ANISOTROPIC SOILS

The rate of seepage per unit length can be calculated by modifying equation $\frac{Q}{L} = kH\frac{n_f}{n_d}$ to

$$\frac{Q}{L} = k'H\frac{n_f}{n_d}$$

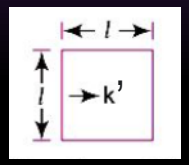
For transformed section, $q = k'\frac{\Delta h}{l}(l \times 1)$

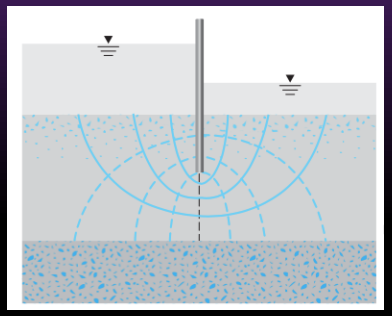
For true section, $q = k_x\frac{\Delta h}{l\sqrt{k_x/k_y}}(l \times 1)$

Equating above two equations

$$k' = \sqrt{k_x k_y}$$

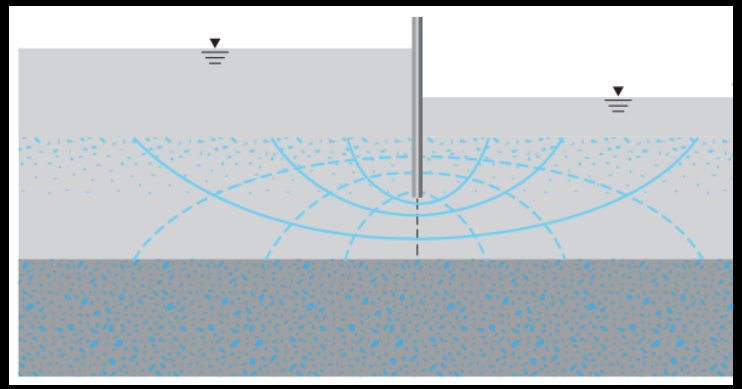
$$\boldsymbol{\frac{Q}{L} = \sqrt{k_x k_y}\, H\frac{n_f}{n_d}}$$





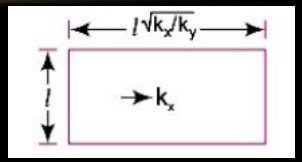
Transformed section

horizontal scale = $\sqrt{k_y/k_x}$ × vertical scale



True section

horizontal scale = vertical scale

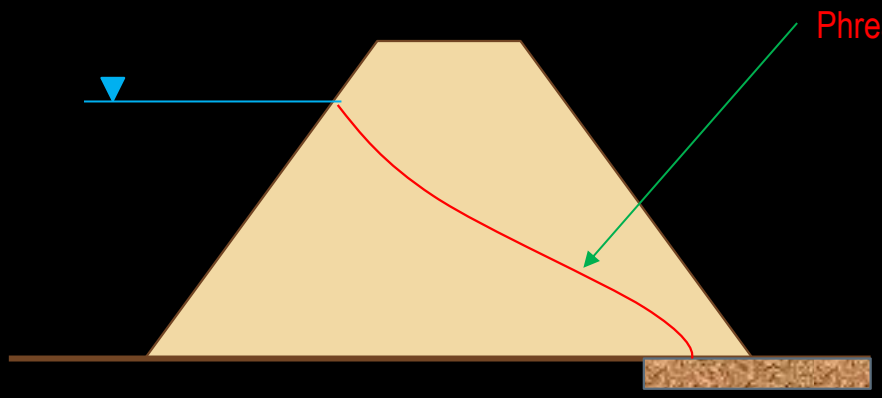


PROBLEM

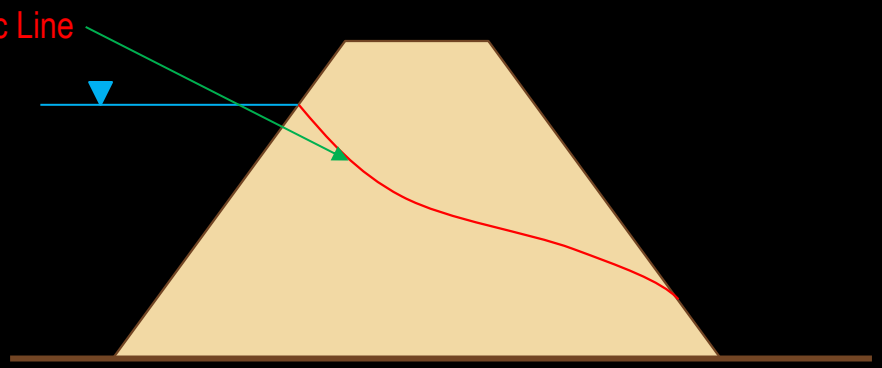
A dam of base width 12m situated on a permeable layer of 10m depth. The head of water at u/s is 4m and at d/s it is 0.5m. The hydraulic conductivity of the permeable layer in the vertical and horizontal directions are 2×10^{-2} mm/s and 4×10^{-2} mm/s, respectively. Draw a flow net and calculate the seepage loss of the dam in m^3/day/m

FLOW THROUGH EARTHEN DAMS

Phreatic Line: The phreatic line or seepage line is defined as the line within a dam section below which there are positive hydrostatic pressures in the dam. The hydrostatic pressure on the phreatic line itself is atmospheric. The phreatic line can be located by (i) analytical method, (ii) graphical method, and (iii) experimental method.



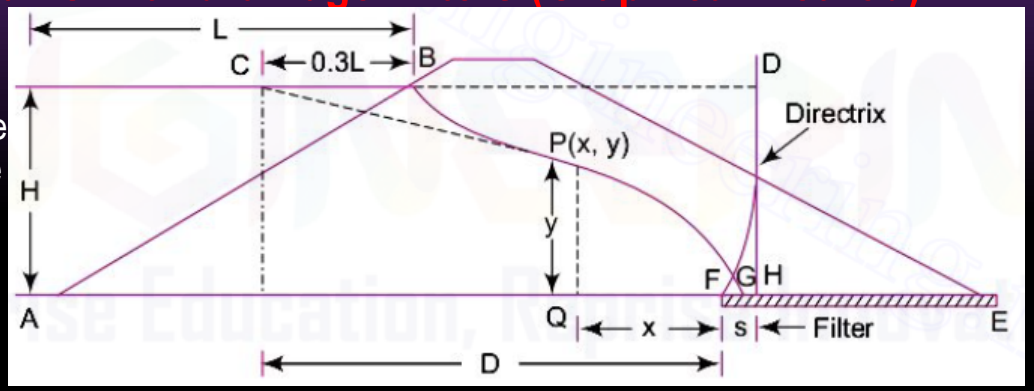
Earthen dam with drainage filter



Earthen dam without drainage filter

FLOW THROUGH EARTHEN DAMS

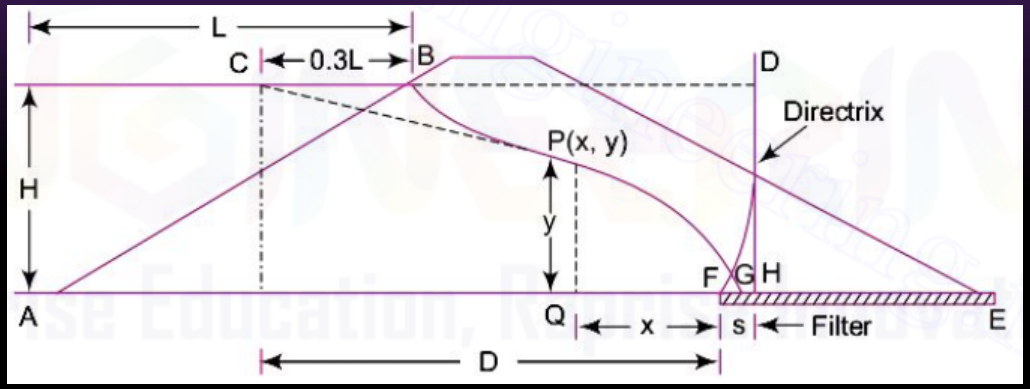
Phreatic Line in an Earthen Dams with drainage Filters (Graphical Method)



1. AB is the u/s face. Let its horizontal projection be L. On the water surface, measure a distance BC=0.3L. Then the point C is the starting point of the base parabola.
2. To locate the directrix of the parabola, we utilize the principle that any point on the parabola is equidistant from the focus as well as from the directrix. Hence with point C as the centre and CF as the radius, draw an arc to cut the horizontal line through CB in D. Draw a vertical tangent to the curve FD at D. Evidently, CD=CF. Hence the vertical line DH is directrix.
3. The last point G on the parabola will lie midway between F and H.
4. In order to locate the intermediate points on the parabola we use the principle that its distances from the focus and directrix must be equal. For example, to locate any point P, draw vertical line QP at any distance x from F. Measure QH. With F as the centre and QH as the radius, draw an arc to cut vertical line through Q in point P.
5. Join all these points to get the base parabola. However, some correction is to be made at the entry point. The phreatic line must start from B and not from C. Also, the phreatic line is a flow line, and must start perpendicularly to the u/s face AB which is a 100% equipotential line. Hence, the portion of the phreatic line at B is sketched free hand in such a way that it starts perpendicularly to AB, and meet the rest of the parabola tangentially (i.e. vertically) at G.

FLOW THROUGH EARTHEN DAMS

Phreatic Line in an Earthen Dams with drainage Filters (Analytical Method)



As per the parabola properties PF = QH → $\sqrt{x^2 + y^2} = x + s$

→ $y^2 = 2xs + s^2$

At point C, x = D, and y = H → $s = \sqrt{D^2 + H^2} - D$

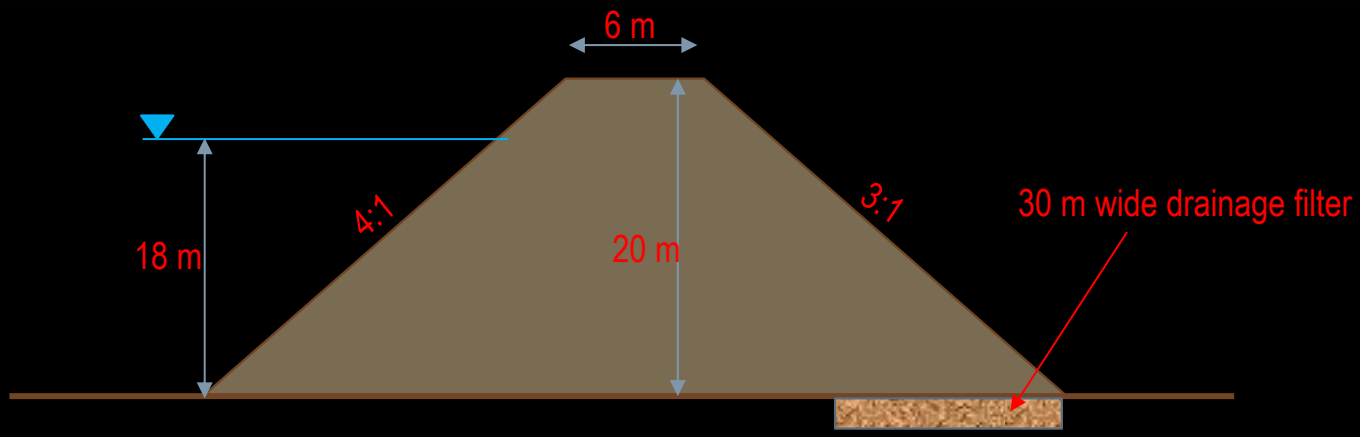
Discharge through the dam:

$q = k\,i\,A \rightarrow q = k\frac{dy}{dx}(y \times 1)$ [as $\frac{dy}{dx} = \frac{s}{\sqrt{(2xs+s^2)}}$]

q = k s

PROBLEM

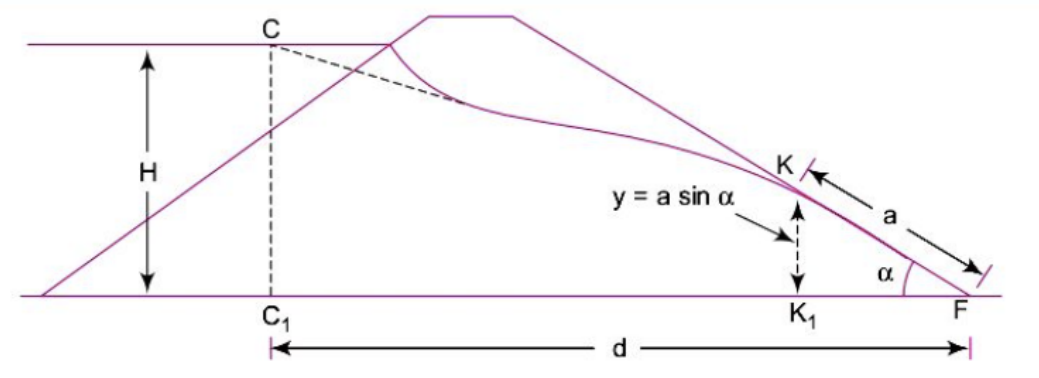
Q.1. For the earth dam of homogeneous section with a horizontal filter as shown in the figure, draw the phreatic line. If the coefficient of permeability of the soil material is 5×10^{-4} cm/sec, find the seepage flow per unit length of the dam.



Q.2. For a homogeneous earth dam 52m high and 2m free board, a flow net was constructed and following results were obtained: Number of potential drops = 25, Number of flow channels = 4, The dam has a horizontal filter of 40m length at its d/s end. Calculate the discharge per metre length of the dam if the hydraulic conductivity of the dam material is 3×10^{-3} cm/sec.

FLOW THROUGH EARTHEN DAMS

Phreatic Line in an Earthen Dams with no drainage Filters



Schaffernak and Van Iterson Method ($\alpha < 30°$)

$$a = \frac{d}{\cos\alpha} - \sqrt{\frac{d^2}{cos^2\alpha} - \frac{H^2}{sin^2\alpha}}$$

$$q = k\ a \sin\alpha \tan\alpha$$

Casagrande's Method ($30° < \alpha < 60°$)

$$a = \sqrt{H^2 + d^2} - \sqrt{d^2 - H^2 cot^2\alpha}$$

$$q = k\ a\ sin^2\ \alpha$$

PROBLEMS

Q.3. For the earth dam of homogeneous section with a horizontal filter as shown in the figure, find the seepage flow per unit length of the dam. The coefficient of permeability of the soil material is 5×10^{-4} cm/sec.