

LECTURE 12

One-dimensional Flow:

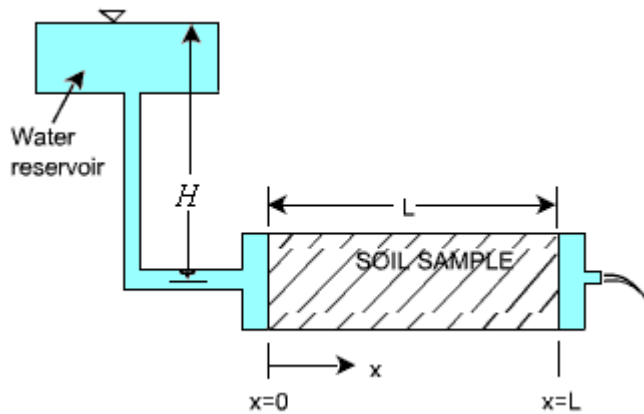
For this, the **Laplace Equation** is $\frac{\partial^2 h}{\partial x^2} = 0$

Integrating twice, a general solution is obtained.

$$\frac{\partial h}{\partial x} = c_1$$

$$h = c_2 + c_1 x$$

The values of constants can be determined from the specific boundary conditions.



As shown, at $x = 0$, $h = H$, and at $x = L$, $h = 0$

Substituting and solving,

$$c_2 = H, \quad c_1 = -\frac{H}{L}$$

The specific solution for flow in the above permeameter is

$$h = H - \frac{H}{L} x$$

which states that head is dissipated in a linearly uniform manner over the entire length of the permeameter.

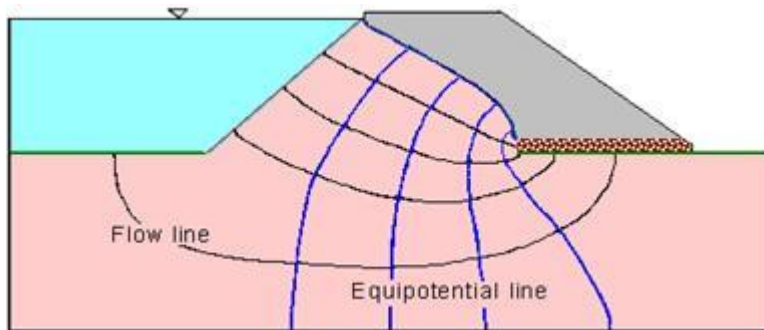
Two-dimensional Flow:

Flow Nets

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:

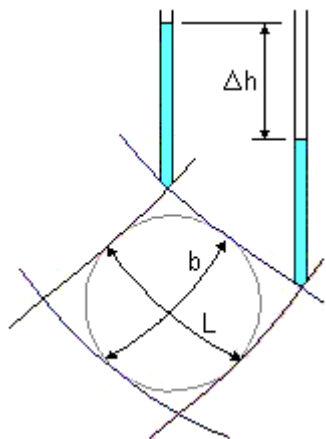
- **Equipotential lines** connecting points of equal total head **h**
- **Flow lines** indicating the direction of seepage down a hydraulic gradient

Two flow lines can never meet and similarly, two equipotential lines can never meet. The space between two adjacent flow lines is known as a **flow channel**, and the figure formed on the flownet between any two adjacent flow lines and two adjacent equipotential lines is referred to as a **field**. Seepage through an embankment dam is shown.



Calculation of flow in a channel

If standpipe piezometers were inserted into the ground with their tips on a single equipotential line, then the water would rise to the same level in each standpipe. The pore pressures would be different because of their different elevations. There can be no flow along an equipotential line as there is no hydraulic gradient.



Consider a field of length **L** within a flow channel. There is a fall of total head **Δh**. The average hydraulic gradient is

$$i = \frac{\Delta h}{L}$$

As the flow lines are **b** apart and considering unit length perpendicular to field, the flow rate is

$$\Delta q = kb \frac{\Delta h}{L}$$

There is an advantage in sketching flow nets in the form of **curvilinear 'squares'** so that a circle can be inscribed within each four-sided figure bounded by two equipotential lines and two flow lines.

In such a square, **b = L**, and the flow rate is obtained as $\Delta q = k \cdot \Delta h$

Thus the flow rate through such a flow channel is the permeability **k** multiplied by the uniform interval Δh between adjacent equipotential lines.

Calculation of total flow

For a complete problem, the flow net can be drawn with the overall head drop **h** divided into **N_d** so that $\Delta h = h / N_d$.

If **N_f** is the no. of flow channels, then the total flow rate is

$$q = \Delta q \cdot N_f = kb \cdot \frac{N_f}{N_d}$$