Permeability and Seepage

Duration = 18 minutes

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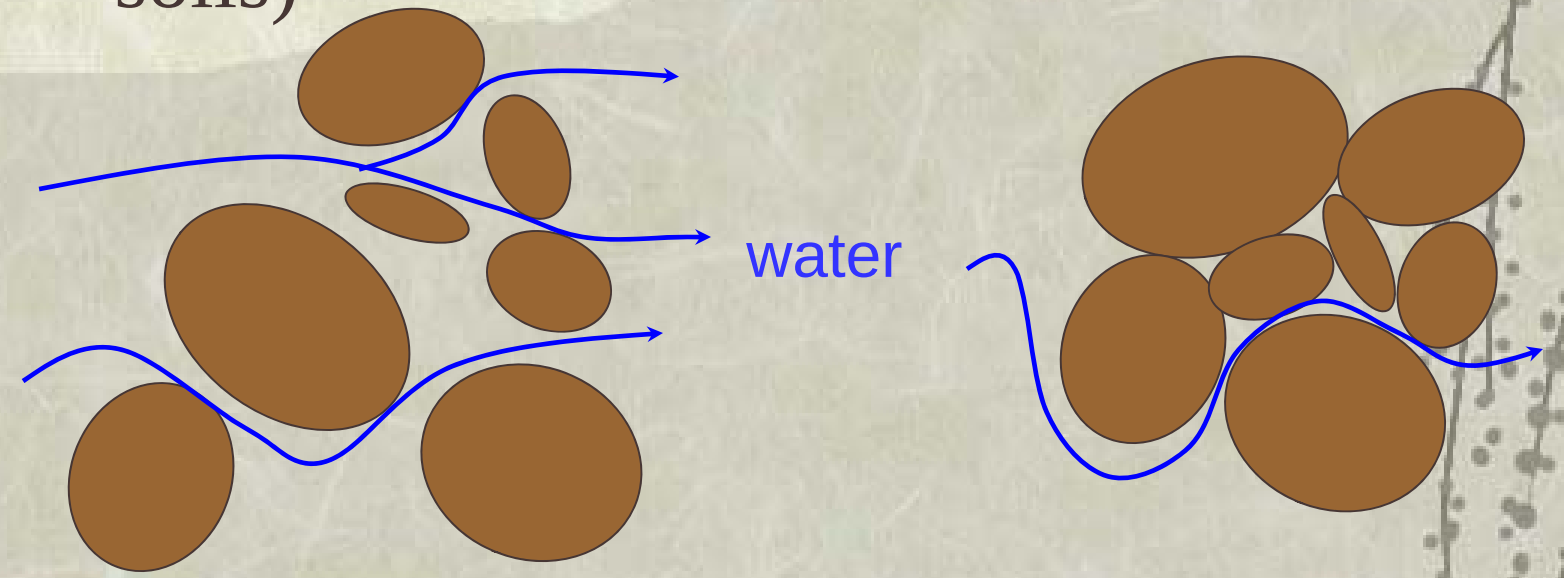
What is permeability?

A measure of how easily a fluid (e.g., water) can pass through a porous medium (e.g., soils)



Loose soil

- easy to flow
- **high** permeability

Dense soil

- difficult to flow
- **low** permeability

Bernoulli's Equation

The energy of a fluid particle (mass = m, velocity = v, pressure = p) is made of:

1. Kinetic energy = $\frac{1}{2} mv^2$

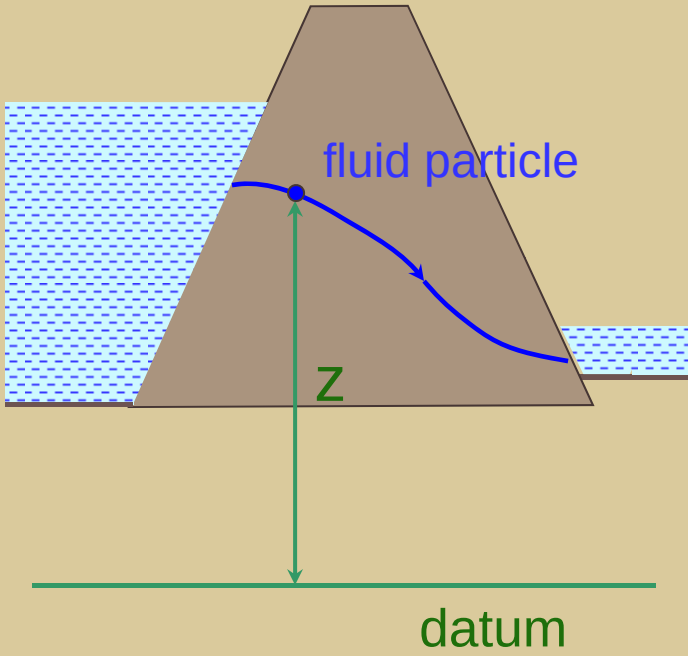
   - due to **velocity**

2. Strain energy = mp/ρ_w

   - due to **pressure**

3. Potential energy = mgz

   - due to **elevation** (z) with respect to a datum

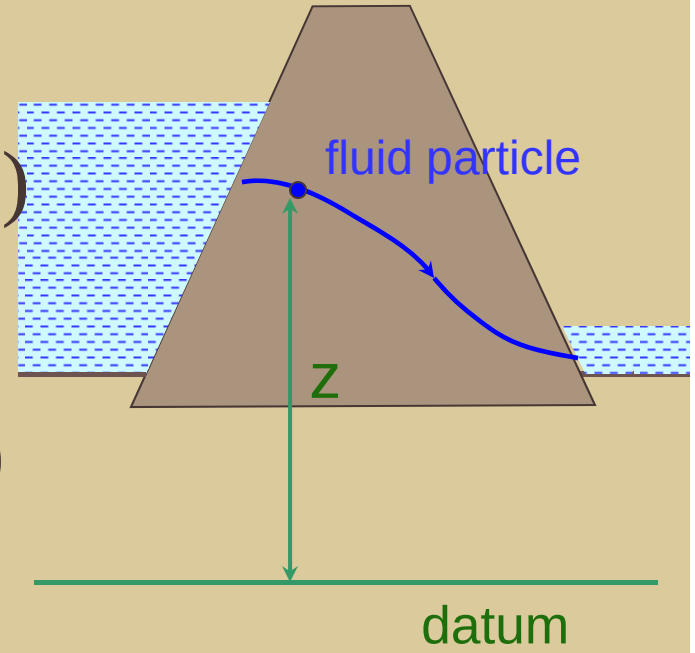


We select the datum at any height.

Bernoulli's Equation

Expressing energy in unit of length:

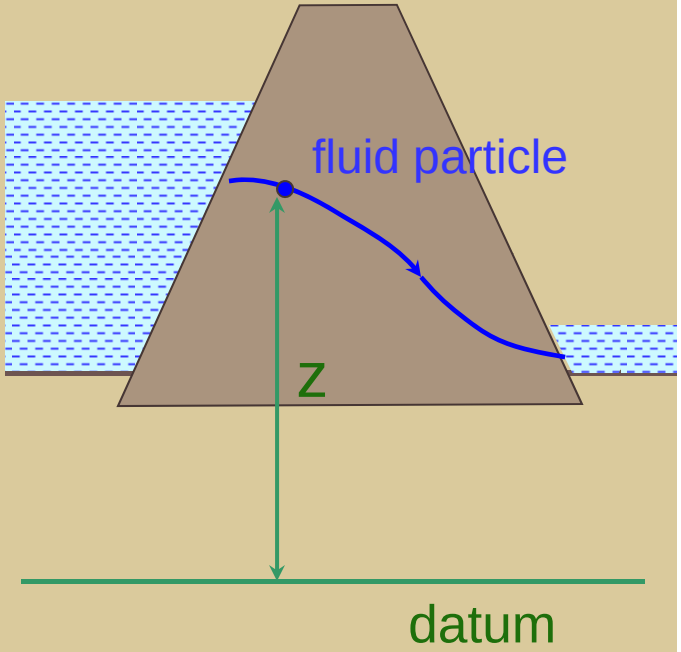
$$\text{Total head} = \begin{cases} \text{Velocity head } (v^2/2g) \\ + \\ \text{Pressure head } (p/\gamma_w) \\ + \\ \text{Elevation head } (z) \end{cases}$$



Bernoulli's Equation

For flow through soils, velocity (and thus velocity head) is very small. Therefore,

Total head = ~~Velocity head~~ (0) + Pressure head + Elevation head

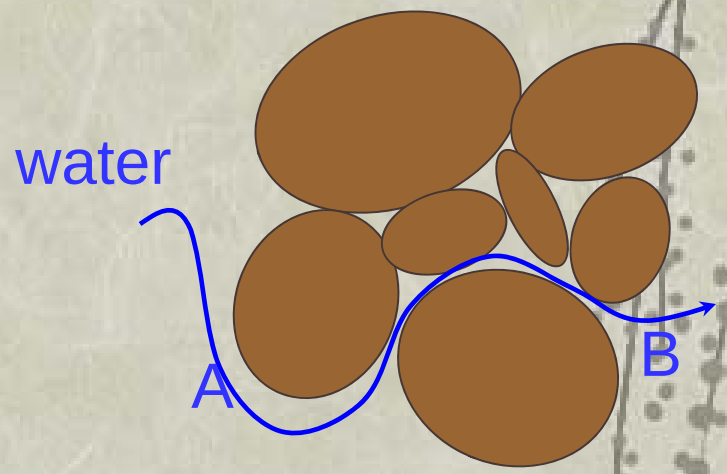


Total head = Pressure head + Elevation head

Some Notes

If flow is from A to B, **total head** is higher at A than at B.

Energy is dissipated in overcoming the soil resistance and hence is the head loss.



Some Notes

At any point within the flow regime:

Pressure head = pore water pressure/γ_w

Elevation head = height **above** the selected datum

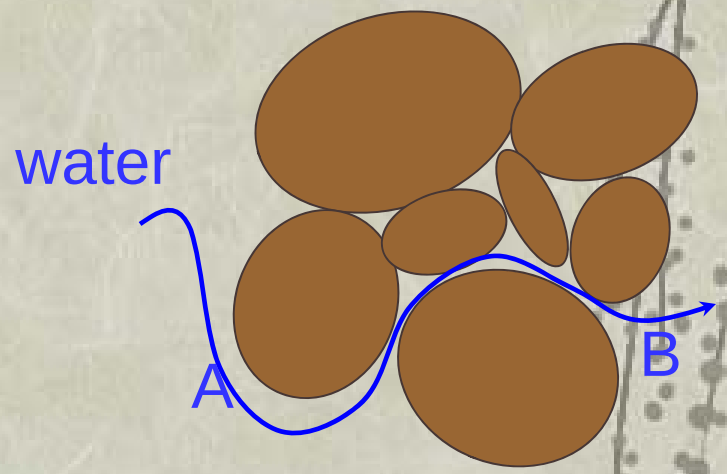
Either of them can be negative.

Some Notes

<u>Hydraulic gradient (i)</u> between A and B is the total head loss per unit length.

$$i = \frac{TH_A - TH_B}{l_{AB}}$$

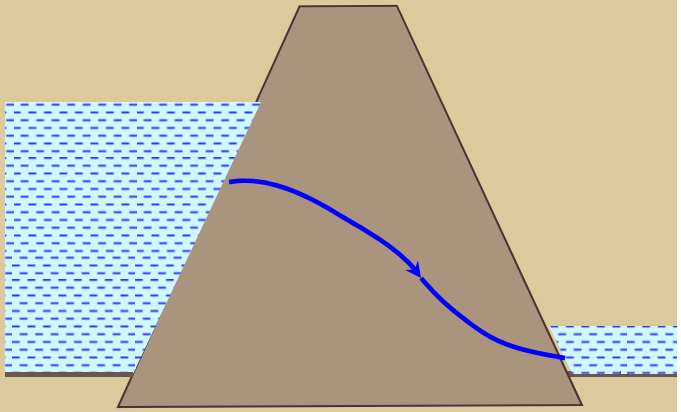
length AB, along the stream line



Darcy's Law

Velocity (**v**) of flow is proportional to the hydraulic gradient (**i**) – Darcy (1856)

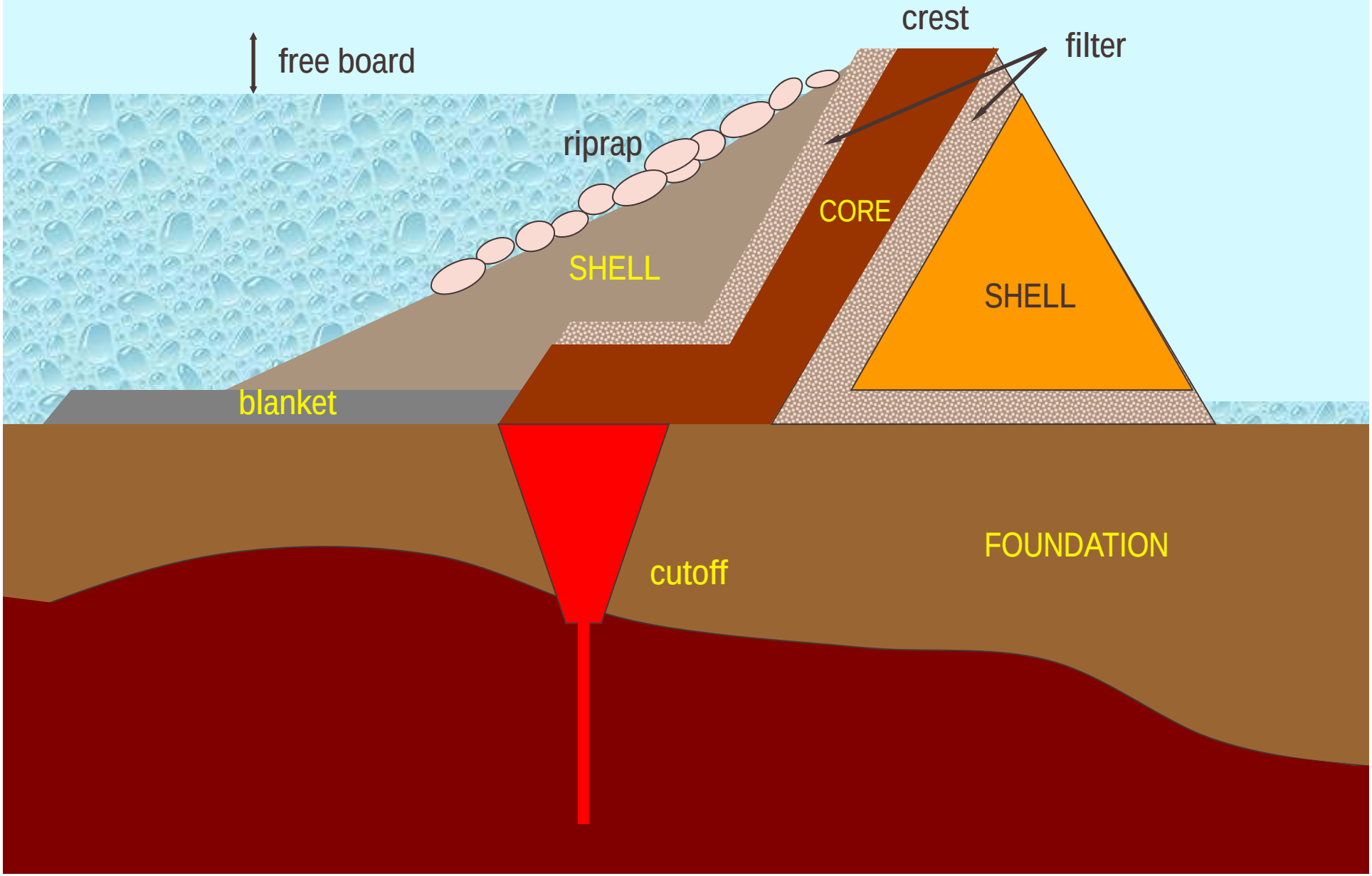
$$v = k\, i$$



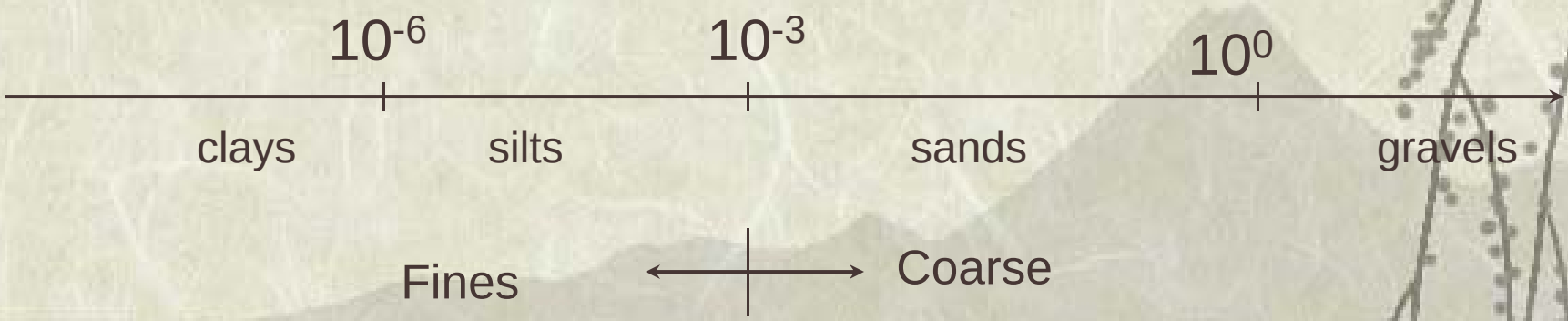
Permeability

- or hydraulic conductivity
- unit of velocity (cm/s, m/s, m/day)

Large Earth Dam



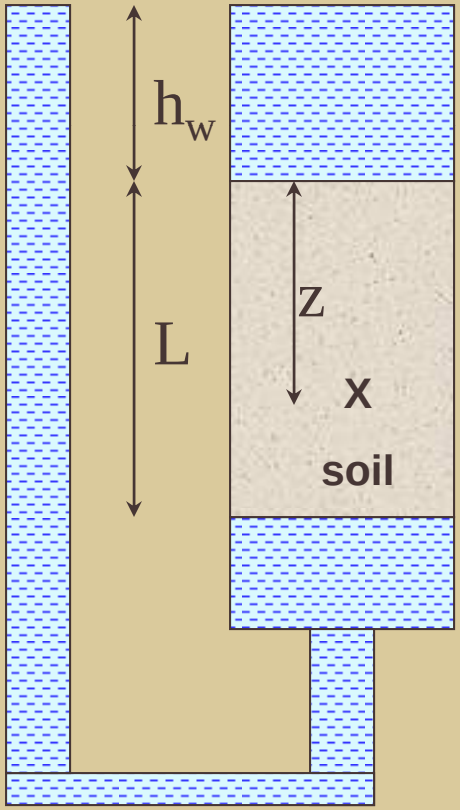
Permeability Values ***(cm/s)***



For coarse grain soils, $k = f(e \text{ or } D_{10})$

Stresses due to Flow

Static Situation (No flow)



At X,

$$\sigma_v = \gamma_w h_w + \gamma_{sat} z$$

$$u = \gamma_w (h_w + z)$$

$$\sigma_v' = \gamma' z$$

Stresses due to Flow

Downward Flow

At X,

$$\sigma_v = \gamma_w h_w + \gamma_{sat} z$$

… as for static case

$$u = \gamma_w h_w + \gamma_w (L - h_L)(z/L)$$

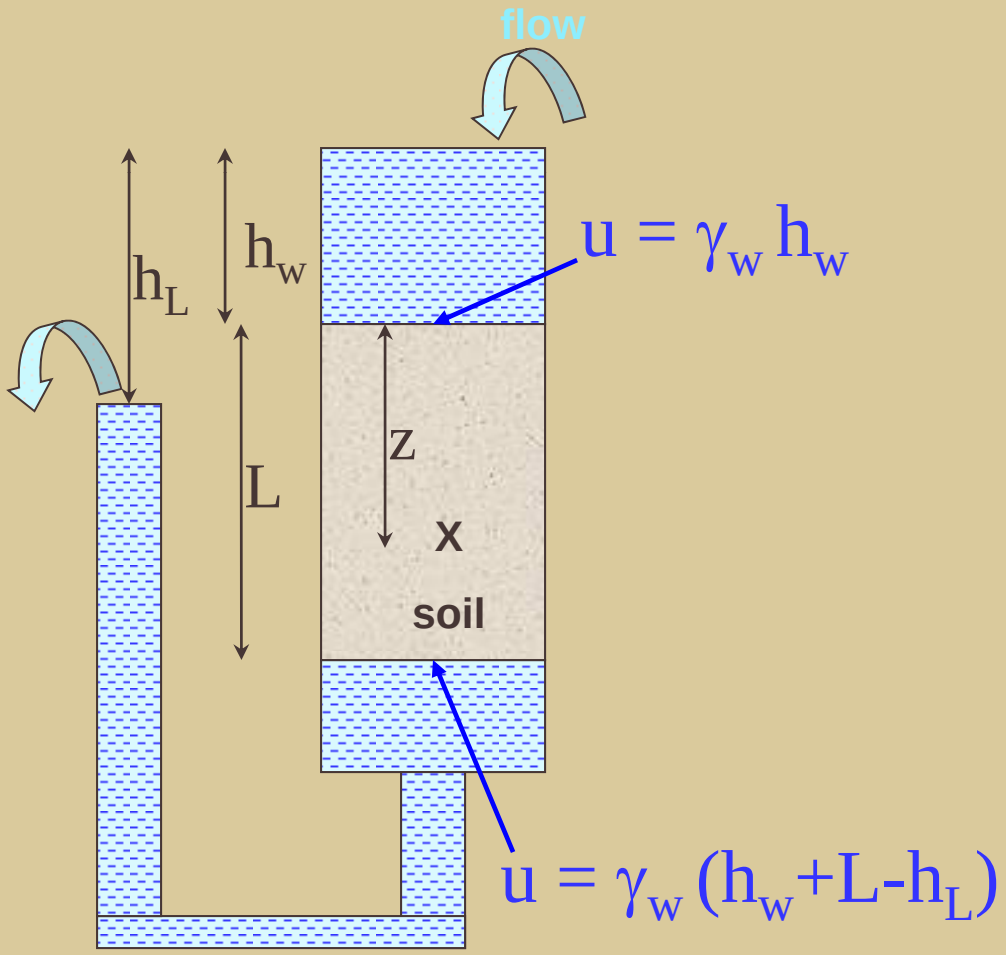
$$= \gamma_w h_w + \gamma_w (z - iz)$$

$$= \gamma_w (h_w + z) - \gamma_w iz$$

Reduction due to flow

$$\sigma_v' = \gamma' z + \gamma_w iz$$

Increase due to flow



Stresses due to Flow

Upward Flow

At X,

$$\sigma_v = \gamma_w h_w + \gamma_{sat} z$$

… as for static case

$$u = \gamma_w h_w + \gamma_w (L+h_L)(z/L)$$

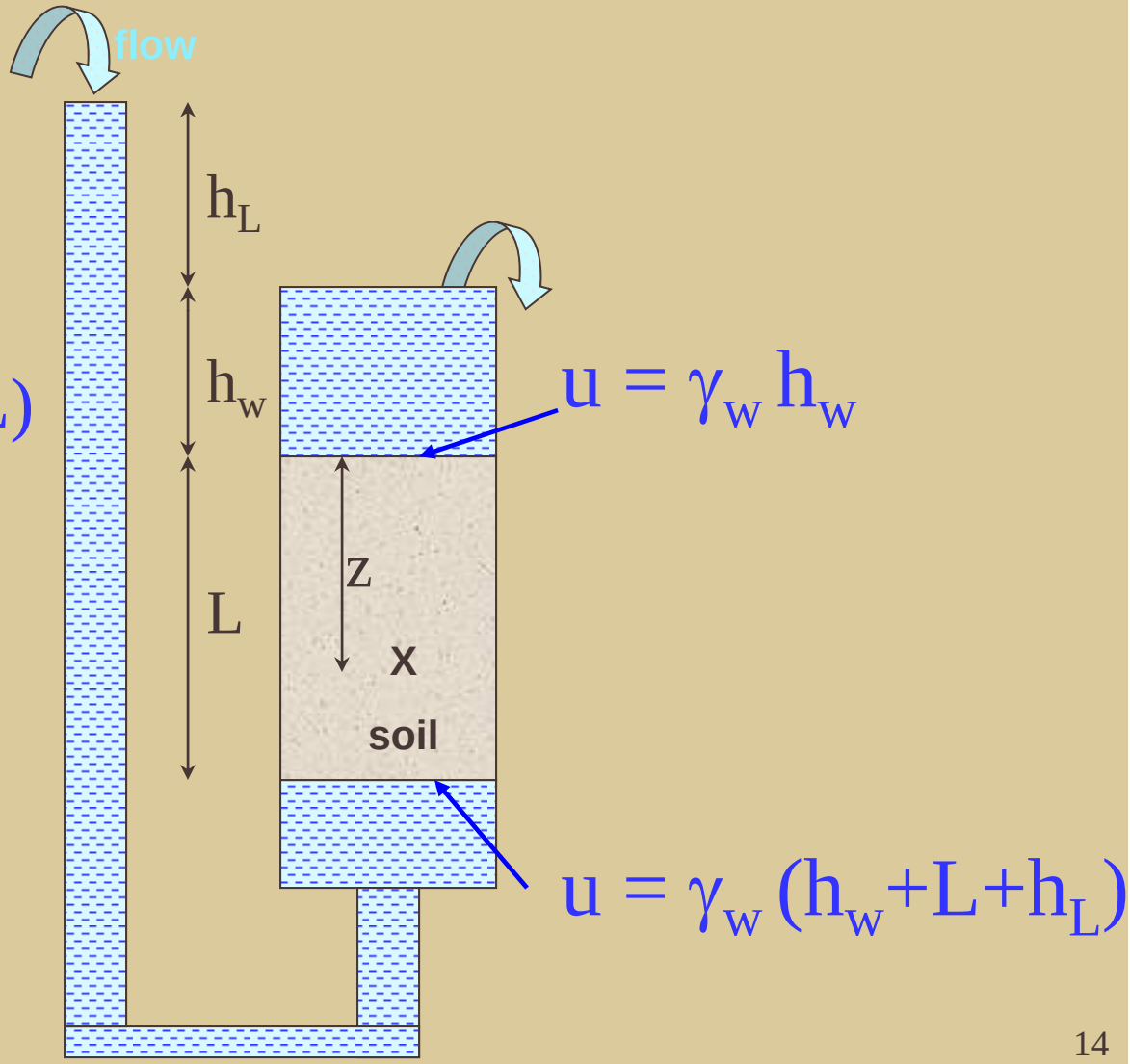
$$= \gamma_w h_w + \gamma_w (z+iz)$$

$$= \gamma_w (h_w+z) + \gamma_w iz$$

Increase due to flow

$$\sigma_v' = \gamma' z - \gamma_w iz$$

Reduction due to flow



*Quick Condition in **Granular Soils***

During upward flow, at X:

$$\sigma_v' = \gamma' z - \gamma_w i z$$

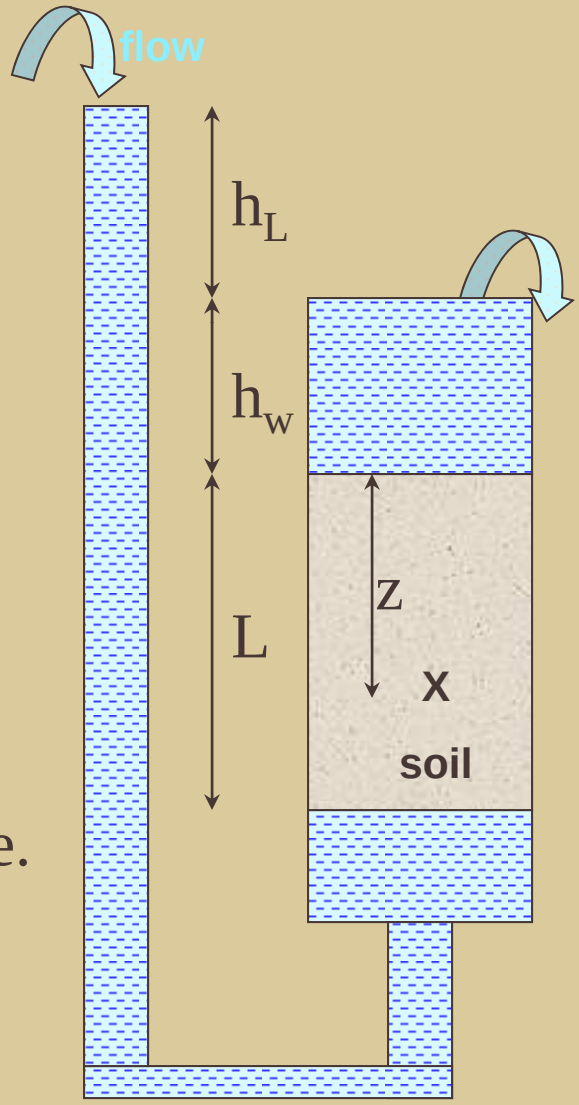
$$= \gamma_w z \left\{ \frac{\gamma'}{\gamma_w} - i \right\}$$

Critical hydraulic gradient (i_c)

If $i > i_c$, the effective stresses is negative.

i.e., no inter-granular contact & thus failure.

- Quick condition



Quicksand

Later… at the same location