*** What to be learned :**

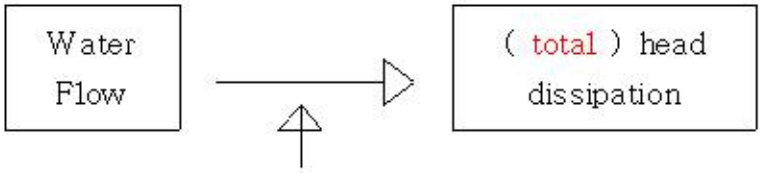
① Seepage force

② Quick condition

③ Frost heave

1. Seepage Force

○ Def. : The force corresponding to the energy transfer taking place from water to solid particles (due to viscous friction) during the water flow thru the pores of soil.



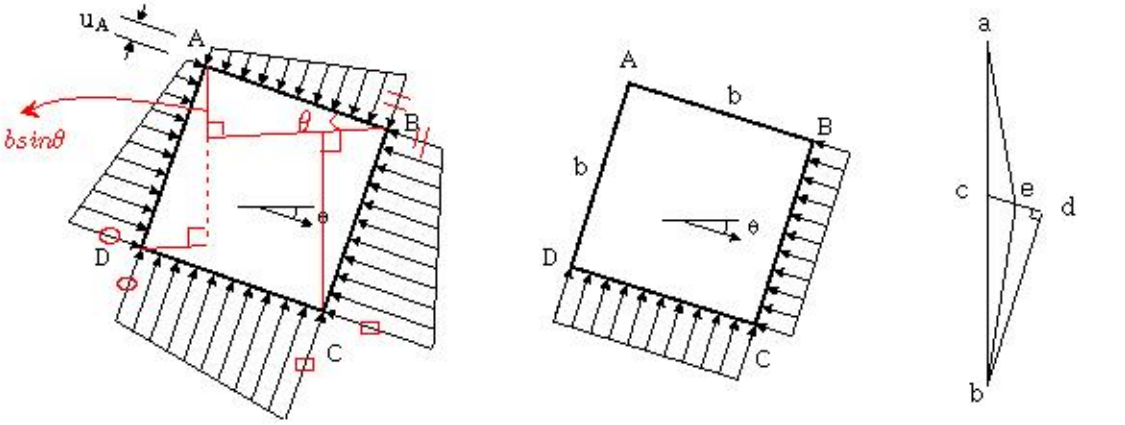
frictional drag on the soil particles
(= seepage force)

○ Resultant body force (= gravitational force + seepage force)

↓

governs the effective normal force

2. Forces Under Seepage Conditions



(a) overall (b) net pressure (c) force polygon

○ $\overline{AD}$ & $\overline{BC}$: Equipotential line

$\overline{AB}$ & $\overline{DC}$: Flow line

○ $\overline{AB} = \overline{BC} = \overline{AD} = \overline{DC} = b$

○ the head drop between $\overline{AD}$ & $\overline{BC} = \Delta h$

○ pore water pressures at pt. A, B, C, & D = u_A, u_B, u_C, u_D

between pts. A&B

Δh_e Δh_t

Thus,

$$u_B = u_A + \gamma_w (b\sin\theta - \Delta h)$$ Δh_e between pts B&C

$$u_C = u_A + \gamma_w (b\sin\theta - \Delta h + b\cos\theta)$$

$$u_D = u_A + \gamma_w (b\cos\theta)$$

Δh_e between pts A&D

and,

$$u_B - u_A = u_C - u_D = \gamma_w (b\sin\theta - \Delta h)$$

$$u_D - u_A = u_C - u_B = \gamma_w b\cos\theta$$

In terms of boundary water force

on $\overline{BC}$: $\gamma_w (b\sin\theta - \Delta h)\cdot b$

$= \gamma_w b^2 \sin\theta \boxed{- \Delta h \gamma_w b}$

on $\overline{CD}$: $\gamma_w b\cos\theta \cdot b$

If there is no seepage, ($\Delta h = 0$)

on $\overline{BC}$: $\gamma_w b^2 \sin\theta$

on $\overline{CD}$: $\gamma_w b^2 \cos\theta$

> The resultant
> $= \gamma_w b^2$

$\therefore$ ($\Delta h \gamma_w b$) is the only difference between the static & seepage cases, and is called the seepage force(J), acting in the direction of (flow)

Let the average hydraulic gradient across the element be $i=(\frac{\Delta h}{b})$

then,

$$J=\Delta h\gamma_w b=\frac{\Delta h}{b}\gamma_w b^2=i\gamma_w b^2=i\gamma_w V$$

the seepage pressure (j)(=seepage force per unit volume),

$$j=i\gamma_w$$

* note that the seepage pressure depends only on
(the value of hydraulic gradient, i)

○ (Refer to Fig. (c) : force polygon)

i) Total wt. of element : $\gamma_{sat}\cdot b^2=\overrightarrow{ab}$

ii) Boundary water force on CD (Seepage & Static case) :

$$\gamma_w\cdot b^2\cos\theta=\overrightarrow{bd}$$

iii) Boundary water force on BC :

- Seepage case

$$\gamma_w b^2\sin\theta-\Delta h\gamma_w b=\overrightarrow{de}$$

- Static case

$$\gamma_w b^2\sin\theta=\overrightarrow{dc}$$

iv) Resultant boundary water force

- Seepage case : $\overrightarrow{be}$
- Static case : $\overrightarrow{bc}$

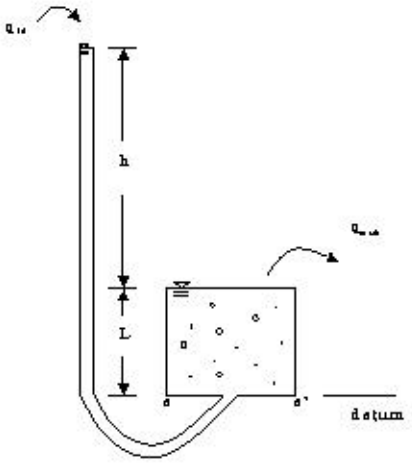
v) Seepage force :

$$\Delta h \gamma_w b = \overrightarrow{ce}$$

vi) Resultant body force

- Seepage case : $\overrightarrow{ae} = \overrightarrow{ab} + \overrightarrow{be} = \overrightarrow{ac} + \overrightarrow{ce}$
- Static case : $\overrightarrow{ac} = \gamma_b \cdot b^2$

3. Quick condition (quick sand, boiling, piping)



- total upward water force at $\overline{aa'}$

$$= (h+L)\gamma_w A \qquad ①$$

- wt. of saturated soil above $\overline{aa'}$

$$= \gamma_t LA = \frac{G+e}{1+e}\gamma_w LA \qquad ②$$

- quick condition occurs if ① ≥ ② , i.e. ,

$$\left(\quad (h+L)\gamma_w A \geq \frac{G+e}{1+e}\gamma_w LA \quad \right)$$

$$\downarrow$$

$$\frac{h}{L}(=i) \geq \frac{G-1}{1+e}$$

* In terms of seepage pressure :

$$\left(\quad J = i\gamma_w V \geq \gamma_b V \rightarrow i \geq \frac{\gamma_b}{\gamma_w}\left(= \frac{G-1}{1+e}\right) \quad \right)$$

4. Frost Heave

○ Def. : the rise of the ground surface due to frost action

○ Freezing of water

- 9% of volume increase for water
- (2.5 ~ 5 %) for soil

○ much greater volume increase possible

- soils having a high percentage of silt-size particles

(∵ have a network of small pores & permeability not too low)

- well-graded soil w/ more than 3% of fines(<0.02 mm)
- Poorly-graded soil w/ more than 10%

○ mechanism :

Ice lenses created in large pores → suction of water by capillary → Excessive water in the upper soil which is frozen.

○ Remedies :

i) Replacement of frost susceptible soils

ii) Lowering the freezing pt. of pore water
- the addition of salt regularly

iii) Restricting the water supply
- install a cut-off blanket in the subsoil

iv) Use of chemical additives
- make the subsoils more/or less permeable (melt or restricted in size)

v) Adding a surcharge load
- make the water table be located more than 6′ below the G.S.
- counteracts the heaving pressure

vi) Use of thermal blanket
- e.g., foam plastic