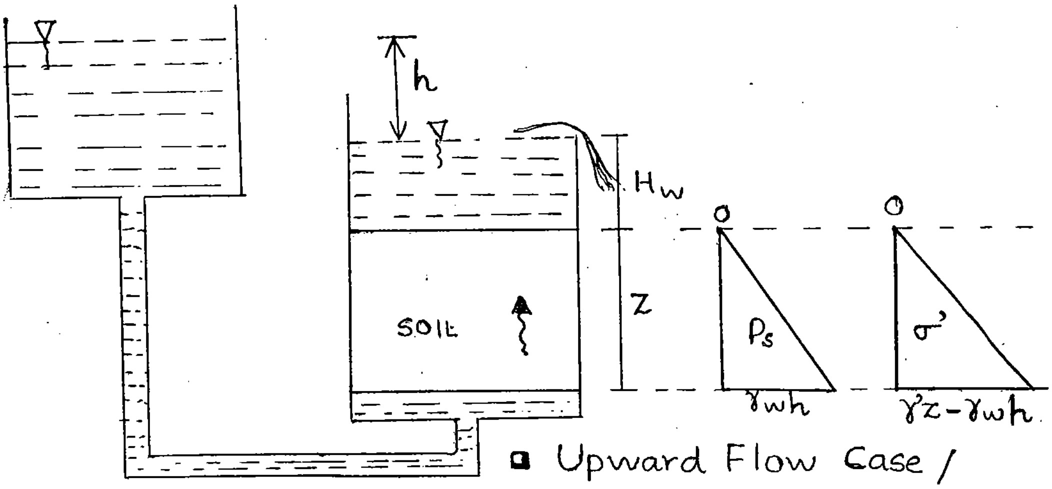
8. SEEPAGE PRESSURE & CRITICAL HYDRAULIC GRADIENT



▪ Upward Flow Case / Upward Seepage

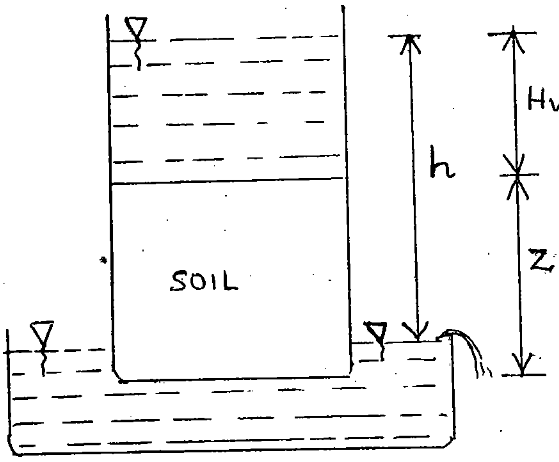
At bottom of soil:

$$\sigma = \gamma_w H_w + \gamma_{sat} \cdot z$$

$$u = \gamma_w (z + H_w + h)$$

$$\sigma' = \sigma - u$$

$$= \gamma' z - \gamma_w h$$



At bottom of soil:

$$\sigma = \gamma_w H_w + \gamma_{sat} z$$

$$u = \gamma_w (z + H_w - h)$$

$$\sigma' = \sigma - u$$

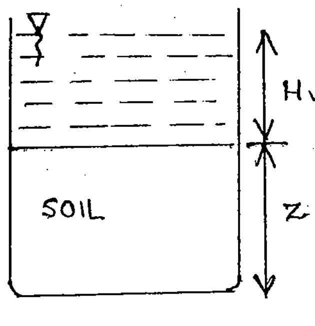
$$= \gamma' z + \gamma_w h$$

▪ Downward Seepage.

$$\sigma = \gamma_w H_w + \gamma_{sat} \cdot z$$

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

$$\sigma' = \sigma - u = \underline{\underline{\gamma' z}}$$



$\therefore$ when there is seepage, $\sigma' = \gamma' z \pm \gamma_w h$

use <u>-ve</u> <u>sign</u> for <u>upward</u> seepage
<u>+ve</u> sign for <u>downward</u> seepage

$$\boxed{\text{Seepage pressure, } P_s = \gamma_w h.}$$

The pressure caused by the seepage water on the soil partic is called seepage pressure.

The seepage pressure always acts in the direction of flow.

Upward Flow: $\gamma' z \downarrow$ $\quad \gamma_w H \uparrow$

Downward Flow: $\gamma' z \downarrow$ $\quad \gamma_w H \downarrow$

Hydraulic Gradient, $i = \frac{h}{z}$.

$$\therefore P_s = \gamma_w h$$
$$= \gamma_w i z$$

Seepage force, $P_s = P_s \cdot A$.
$$= \gamma_w \cdot i \cdot z \cdot A.$$

$A \rightarrow$ area at bottom of soil.

$\therefore$ Seepage force per unit volume of soil $= \underline{\underline{\gamma_w i}}$

→ Critical Hydraulic Gradient; i_c.

It is the hydraulic gradient at critical condition. $(\sigma' = 0)$.

In an upward seepage, $\sigma' = \gamma' z - \gamma_w h$.

At critical condition $(\sigma' = 0)$; $\gamma_w h = \gamma' z$

$$\Rightarrow \frac{h}{z} = \frac{\gamma'}{\gamma_w}$$

$$\therefore \boxed{i_c = \frac{\gamma'}{\gamma_w}}$$

$$\boxed{i_c = \frac{G-1}{1+e} = (G-1)(1-n)}$$

For soils, $i_c \approx 1$. $(G = 2.6 - 2.85$ & $e = 0.6 - 0.85)$

→ Quick Sand & Quick Condition or Boiling Condition.

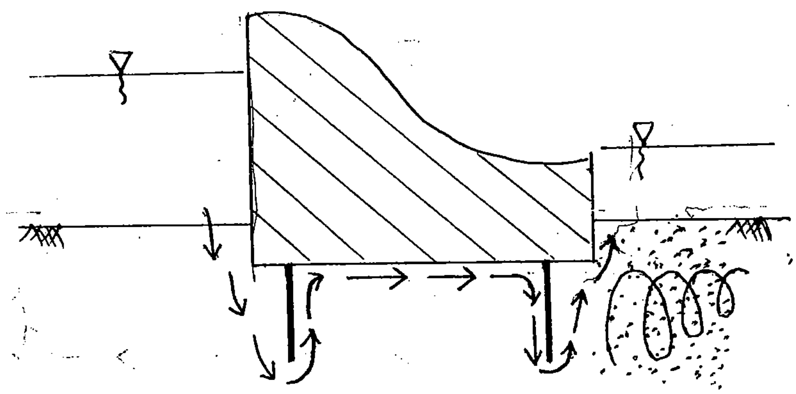
Shear strength, $s = c' + \sigma' \tan\phi'$

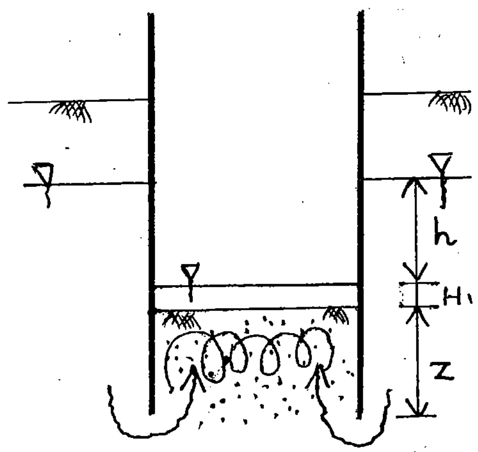
For cohesionless soils, $s = \sigma' \tan\phi'$

In an upward seepage, $\sigma' = \gamma' z - \gamma_w h$.

At critical condition $(\sigma' = 0)$, shear strength of cohesionless soil becomes zero and the soil behaves like a boiling liquid. This phenomenon is called Quick Condition. It occurs only in cohesionless soils.

Quick condition is generally observed in fine sand and silts. In the case of gravel and coarse sand, though they are cohesionless, quick sand condition is not common, sin these are highly permeable.





Practically, quick sand condition occurs at the bottom or d/s side of hydraulic structures. This is also experienced during construction activities in regions where WT is closer to GL.

* To prevent Quick Condition

- Provide more depth of sheet piles and reduce the hydraulic gradient.
- Keep some depths of water (Hw) in the trench without completely dewatering.
- Lower down the surrounding WT.
* Apply some surcharge load intensity (q) on top of soil, at D/S of hydraulic structures.

Let i be actual hydraulic gradient $\left(= \frac{h}{z}\right)$

i_c be critical hydraulic gradient of soil $\left(= \frac{G-1}{1+e}\right)$.

If $i \geq i_c$, quick condition occurs.

To avoid quick condition, i must be kept less than i_c.

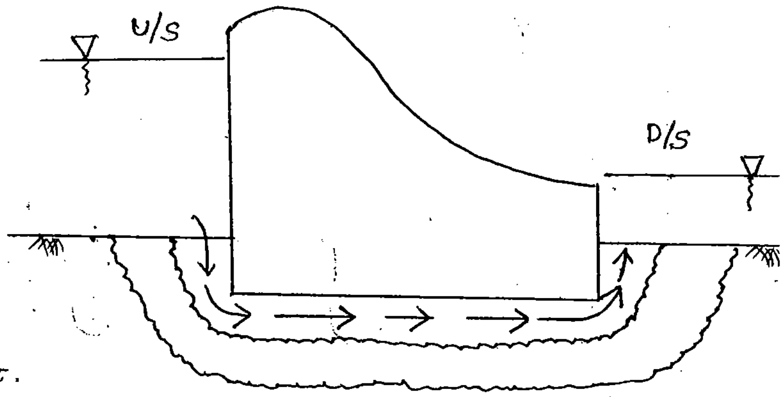
$\therefore$ FOS against quick condition, $\boxed{F = \frac{i_c}{i}}$

* The minimum head required to cause quick condition,

$$h = i_c \cdot z.$$

9th Sept, TUESDAY

→ Piping: (undermining)



- gradual erosion of soil particles.
- It occurs when $\sigma' = 0$ in case of cohesionless soils like fine sand and silt.

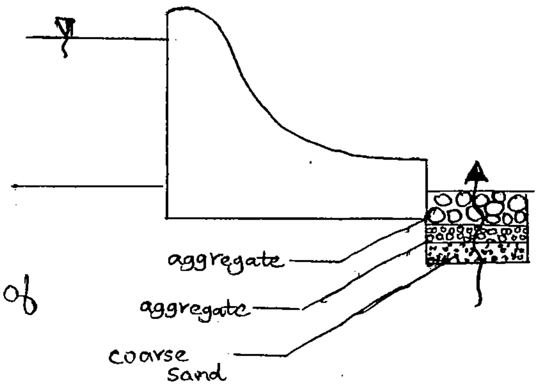
Let i_{exit} be hydraulic gradient at exit point.

$$\text{FOS against piping} = \frac{i_c}{i_{exit}}$$

* To prevent Piping:

– provide sheet piles in the foundation to reduce the hydraulic gradient.

– provide inverted filter on D/S.



▫ Terzaghi's criteria for design of filter :

(i) $\dfrac{(D_{15})_{filter}}{(D_{15})_{base}} \geq 5$; to allow escape of water

(ii) $\dfrac{(D_{15})_{filter}}{(D_{85})_{base}} \leq 5$; to prevent escape of soil particles.

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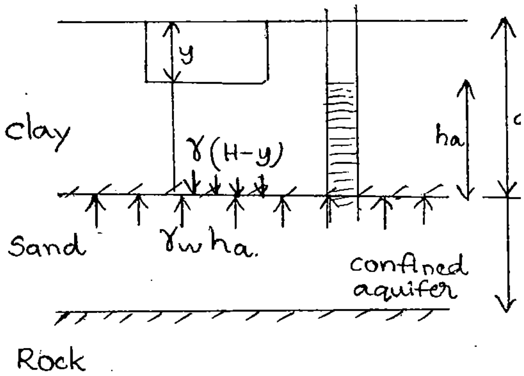


1. At critical condition,

downward pr. = uplift pressure.

$\gamma(H-y) = \gamma_w h_a$.

$20(9-y) = 10 \times 6$.

$y = 9-3 = \underline{\underline{6\,m}}$

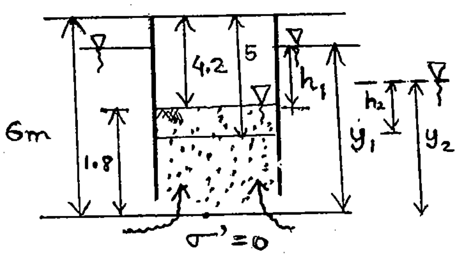
2. If $y = 7\,m$,

$\gamma(H-y) = \gamma_w h_a$

$20(9-7) = 10\, h_a$

$\therefore h_a = 4\,m$.

$\therefore$ Water is to be lowered by $6-4 = \underline{\underline{2\,m}}$



3. $\sigma' = \gamma' z - \gamma_w h_1$

$0 = 11 \times 1.8 - 10 \times h_1$

$\therefore h_1 = 1.98\,m$

$y_1 = 1.8 + 1.98 = \underline{\underline{3.78\,m}}$

When depth of excavation increased to 5m,

$0 = 11 \times 1 - 10\, h_2$

$h_2 = 1.1 \text{ m}$

$y_2 = 1 + 1.1 = 2.1 \text{ m}$

$y_1 - y_2 = 3.78 - 2.10 = \underline{\underline{1.68 \text{ m}}}$

$\Delta z . \gamma_{sat} = \Delta h . \gamma_w$

$(1.8 - 1)(11 + 10) = \Delta y . 10$

$0.8 \times 2.1 = \Delta y$

$\therefore \underline{\underline{\Delta y}} = 1.68 \text{ m}$

04. $e = 0.8, \quad G = 2.65, \quad z = 10 \text{ cm}.$

$$I_c = \frac{G-1}{1+e} = \frac{1.65}{1.8} = 0.916$$

$h = I_c . z = \underline{\underline{9.16 \text{ cm}}}$

05. $Q = kiA.$

$0.04 = 2 \times 10^{-3} \times i \times 45$

$i = 0.44.$

$h = iz = 0.44 \times 10 = \underline{\underline{4.4 \text{ cm}}}$

06. $\sigma' = \gamma' z - \gamma_w h.$

$= (1.93 - 1) \times 10 - 1(4.4).$

$= \underline{\underline{4.86}} \text{ g/cm}^2$