Chapter 3 : Seepage

What to be learned :

① Why the seepage occurs ?

② What governs the flow characteristics thru soils ? k & i

③ What affects the k of soils ?

④ How the k estimated ?

Prel.

○ Head(h) : Energy per unit of mass contributing to the movement of fluid(thru soils)

- Pressure head, $h_p = \dfrac{(\text{Water Pressure})}{(\ \gamma_w\ )}$

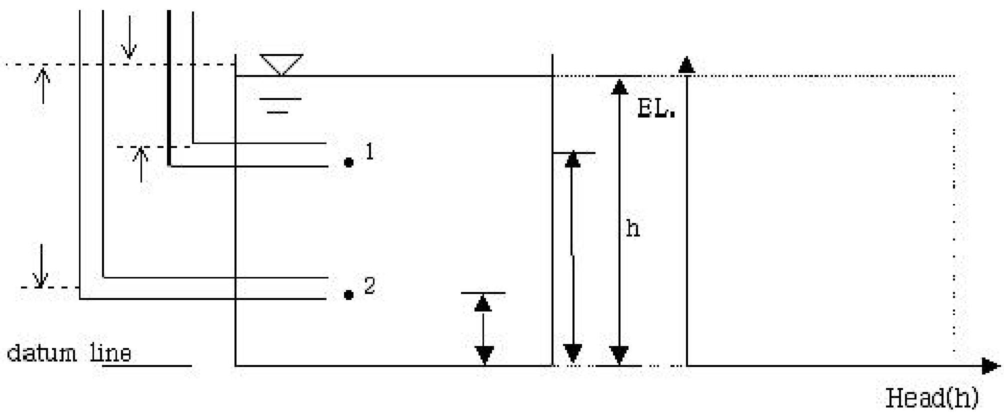
- Elevation head, h_e =distance from datum

(- Velocity head, $h_v \leftarrow$ neglected ∵ <<1)

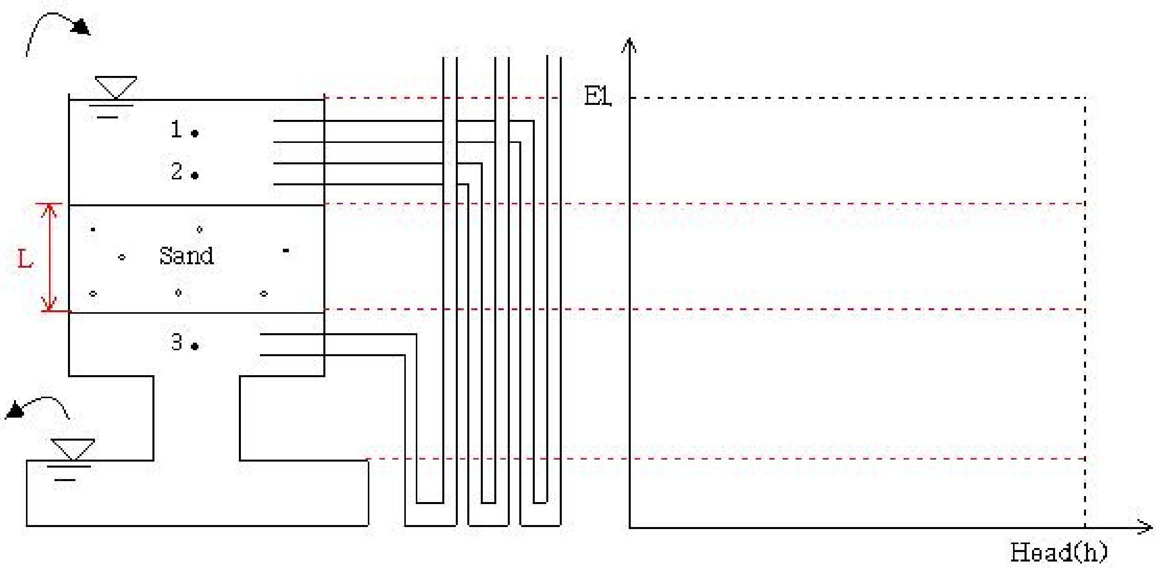
- Total head, $h_t = (\quad h_p + h_e \quad)$

Examples :

①



②



(Fig.1)

1. Darcy's law (experimentally derived)

◎ $\dfrac{q}{A} \propto i$

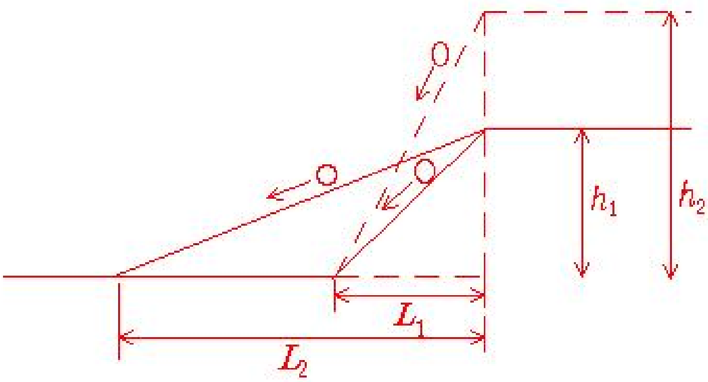
in which q: the rate of flow

A: the x-sectional area of water flow

i: the hydraulic gradient

◎ $\dfrac{q}{A} = ki \rightarrow \; q = kiA = k\dfrac{(h_2 - h_3)}{(\;L\;)}A$ [from Fig.1]

k: Darcy's coefficient of permeability



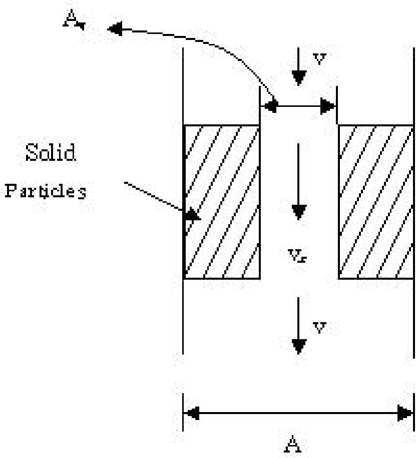
- **gradient(i) : 기울기, 경사도**

$i = \dfrac{h}{L}$

$h_1/L_1 > h_1/L_2$, $h_2/L_1 > h_1/L_1$

◎ flow velocity

$\frac{q}{A} = ki = v$: apparent velocity (1 → 2)



$q = vA = v_s A_v$

$$v_s = v\frac{A}{A_v} = v\frac{AL}{A_v L} = v\frac{(\ V\ )}{(\ V_v\ )} = \frac{(\ v\ )}{(\ n\ )}$$

porosity

= Seepage velocity (2 → 3)

◎ Factors influencing the permeability of soils

1) Size of the soil grains

k ~ (D_{10}^2) [by Hazen, ($\underset{\text{cm/sec}}{k} = 100\underset{\text{cm}}{D_{10}^2}$)]

∵ the pore size is related to the particle size

2) properties of pore fluids

$$k_{20℃} = k_T \frac{\mu_T}{\mu_{20℃}}$$

where, μ_T : viscosity of fluid at T ℃

3) void ratio of soils

(**Linear relations**)

k ~ $e^3/(1+e)$, k ~ $e^2/(1+e)$

* $\log k \sim e$, $k \sim e^2$

4) The shapes and arrangements of pores

= The shapes and arrangement of (**soil particles**)

5) Degree of (**saturation**)

2. Laboratory test methods of permeability

◎ What to obtain from the tests, and how to use it?

1) Determine the relationship between e and k

2) Predict k, after obtaining $e_{in-situ}$

◎ Lab. methods of measuring k

1) Variable head permeability test

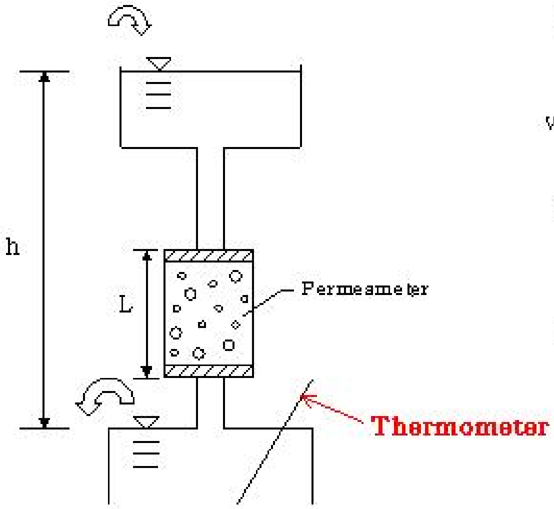
2) Constant head permeability test

3) Capillary method - **not accurate**

4) Use of consolidation test data - **cohesive soil only**

◎ Test Set-Up

1) Constant Head Test



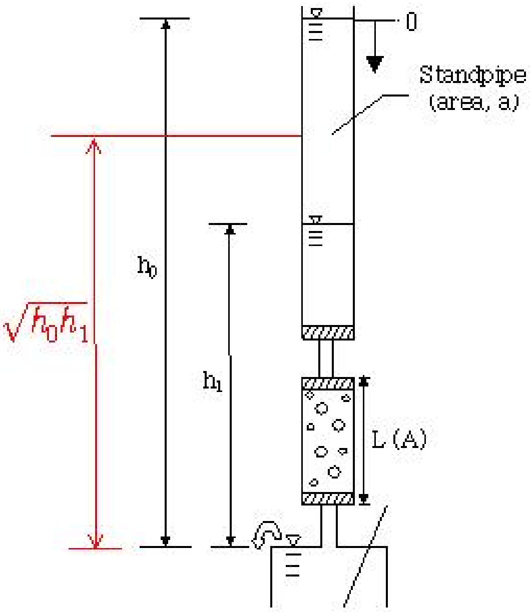
$$k = \underbrace{\frac{Q}{t}}_{q}\,\underbrace{\frac{L}{h}}_{\frac{1}{i}}\,\frac{1}{A} = \frac{q}{iA} \quad \leftarrow q = kiA$$

where

Q : total quantity of water which flowed thru in time t

h : total head loss

2) Variable head test



$$k = 2.3\,\frac{a\,L}{A(t_1 - t_0)}\,\log\frac{h_0}{h_1}$$

$$\begin{aligned} q &= a \cdot \left(-\frac{dh}{dt}\right) \\ &= k\,i\,A \\ &= k\,\frac{h}{L}\,A \end{aligned}$$

$$-a\frac{dh}{dt} = A\,k\,\frac{h}{L}$$

$$-a\int_{h_0}^{h_1}\frac{dh}{h} = \frac{Ak}{L}\int_{t_0}^{t_1}dt$$

$$\therefore k = 2.3\frac{aL}{A(t_1 - t_0)}\log\frac{h_0}{h_1}$$

○ $\dfrac{h_0}{\sqrt{h_0 h_1}} = \dfrac{\sqrt{h_0 h_1}}{h_1}$

→ 3% difference in time acceptable

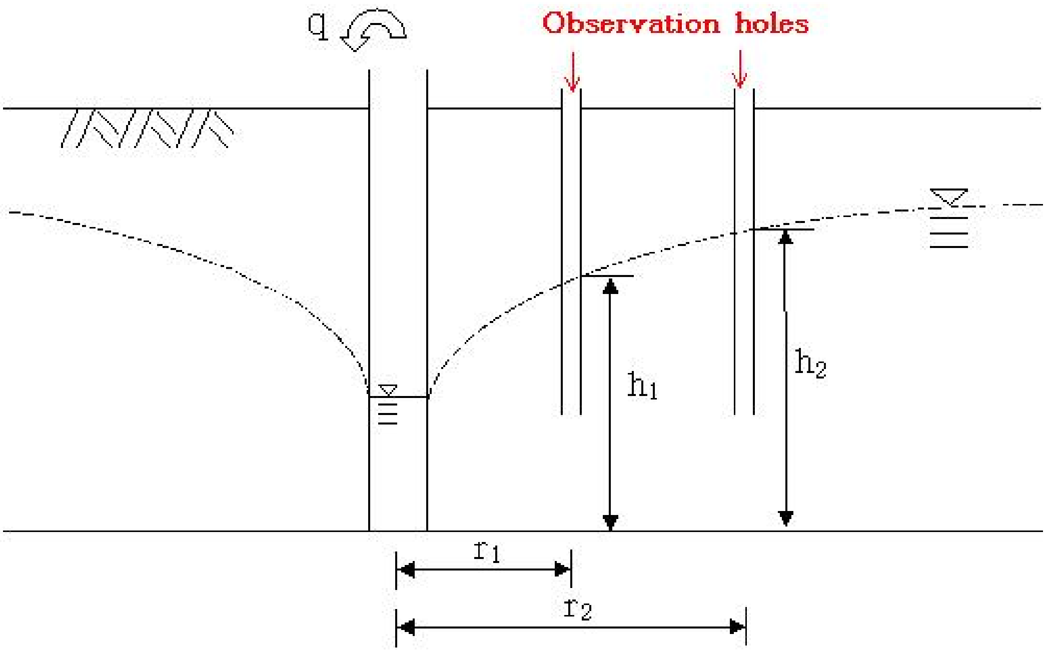
○ Maximum grain size

To keep the water flow thru permeameter **be laminar flow**

$$D_{largest} \le \frac{A}{15 \sim 20}$$

3. In-situ test methods

◎ Well pumping test

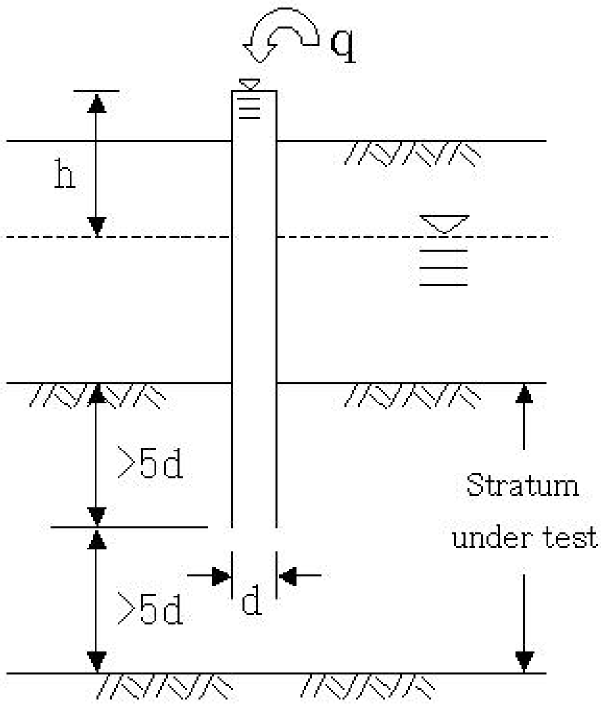


$i_r = -\dfrac{dh}{dr}$, $A = 2\pi r h$, $q = 2\pi r h k \dfrac{dh}{dr}$ ←**Dupuit assumption**

: i at r is constant *w/depth*

$$\rightarrow q\int_{r_1}^{r_2}\frac{dr}{r} = 2\pi k\int_{h_1}^{h_2} h\ dh \rightarrow k = \frac{2.3\ q\log\dfrac{r_2}{r_1}}{\pi\,(h_2^2 - h_1^2)}$$

◎ Constant Head Test



$$k = \frac{q}{2.75\ dh}$$

(from electrical analogy experiments)

* Electrical analogy :
- continuous model **- conducting paper**
- lumped parameter model **- resistance (electric)**
- Ref. : "Principles of Soil Mechanics" by R. F. Scott (pp 120~133)