CH.5

Water Flow through Soils

5.0 Introduction

- Leakage through earth dams
- Soil consolidation
- Foundation settlement

Flow - steady Soil - saturated
- unsteady - unsaturated

Steady flow in saturated soils

- Flow paths
  Flow lines

5.1 Darcy's Law 1856

- Constant water pressure differences (h) between ends of soil sample Fig. 5.1
- Quantity of water flow (Q) per time (+)

Flow rate: $q = \dfrac{Q}{t} \times \dfrac{Ah}{L}$, $\dfrac{q}{a} = v$: velocity

$v \times \dfrac{h}{L}$ $\dfrac{h}{L} = i$: hydraulic gradient
(total head loss per unit length of flow path)

$v \times i$

$v = k\,i$, k: coefficient of permeability (m/sec)

discharge velocity: volume of water that percolates in a unit time across a unit area ⊥ to flow path.

- Actual seepage velocity = effective velocity (v_e)

$$q = v \cdot A = v_e \cdot A_{voids} = v_e \cdot \eta A$$

$$\text{porosity} = \frac{V_v}{V} = \frac{A_v}{A} \qquad \text{Fig. } \underline{5.2}$$

$$v_e = \frac{v}{h}$$

- $$k = \frac{g_w}{h} K$$

  K — absolute permeability (m^2)

  h — viscosity

$$K = k \frac{h}{g_w}$$

$$K_{20} = K_T$$

$$k_{20} \frac{h_{20}}{g_{w,20}} = k_T \frac{h_T}{g_{w,T}} \qquad \Rightarrow \qquad k_T = \left(\frac{h_{20}}{h_T}\right) k_{20}$$

5.2 Permeability measurement - Lab - constant-head test
- falling-head test

Constant: $$k = \frac{q}{iA}$$

Falling: $$k = \frac{2.3\ a\ L}{A\ (t_2 \cdot t_1)} \log \frac{h_1}{h_2}$$

<u>Table 5.1</u>

5.3 Permeability meas. ----- Field

- Pumping test
- Seepage velocity
- Open-end tests

Flow - Laminar
 - Turbulent

5.4 Hydraulic heads in soils

ft. lb./ lb = (ft.)

Head: <u>energy per unit weight</u>
(h)
\ Potential & kinetic

h_p $\rightarrow$ pressure head presume $\div$ unit weight of fluid

h_e $\rightarrow$ elevation head

h_v $\rightarrow$ velocity head

$$h = h_p + h_e + h_v = \frac{u}{g_w} + Z + \frac{v^2}{2g} = \text{const}$$

$$h = h_p + h_e = \frac{u}{g_w} + Z$$

* Fig. 5.8

  - Datum: any elevation
  - Flow depends only on the diff in total head

  Direction:

  1. Find total head (h)
  2. Find elevation (h_c)
  3. Compute pressure head (h_p)

* Fig. 5.9

* Table 5.4

* Fig. 5.10

* Elevation head: depends on datum

* Pressure head:
  - actual pressure in water (pore water pressure)
  - height of rise in piezometers (pressure meters) above point under consideration

* Total head: $h_e + h_p \Rightarrow$ flow gradient

Layered soil -------- Ex. 5.1
5.2

5.5 Basic equation for fluid flow in soil

* P. 151-153

Steady Flow

Laplace's equation for steady state fluid flow

3D → 2D → 1D

Example 5.3

5.6 Analytical/numerical methods

5.7 Flow net 1-D flow

Graphical solution: (Trial & Error)

2 families of curve intersecting at 90^o (orthogonal)

→ Flow lines
Flow paths

→ Equipotential lines
(point of equal total head)

Flow net

Curvilinear squares

5.8 Flow net for 2-D confined flow

- Nonlinear flow path
- Confined between two impervious boundaries

1-D - Darcy's Law
- Head concept (Bernoulli's equation)

2-D - Graphical method – Laplace's equation
Flow net (trial & error)

Flow net

1. Boundary condition

2. Draw the net - flow lines ⊥ orthogonal
- equipotential lines

* Feel.

- Time consuming
- Accurate enough
  - seepage quantity
  - pore water pressure
  - gradient

(Isotropic)

* Fig. 5.19

- Curvilinear squares

(11) equipotential lines (points of total equal heads)

(10) equipotential drops (each = 1.0 ft/drop) is lost

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

(6) flow lines ⇒ (5) flow paths channels

* Steps P. 165-166

Determination of rate of flow
* 166-167

N_f
N_e
ΔH

5.9
5.10

5.11 Seepage force

$$i_c = \frac{g_{sat} - g_w}{g_w} = \frac{g'}{g_w} = 1$$

$$= \frac{(G_s + e)}{1 + e} - 1 = \frac{G_s + e - 1 - e}{1 + e}$$

$$i_c = \frac{G_s - 1}{1 + e}$$