Study about soil water- Soil hydraulics

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Abstract: Water in soil adversely affects cohesive soils by reducing the cohesion by softening, and may cause bulking of cohesionless soils depending on the amount of water present. If sufficient water is present to develop pore pressure [changes in water height in a piezometer tube (see Fig. 2-7a)] there may be a marked reduction in the $\sigma' \tan\phi$ component of the shear strength. Permeability is the facility for water flow through a soil mass. It is a major factor in soil drainage, well water supply, and construction dewatering. All natural soil deposits contain free water in their voids. After prolonged dry periods the amount of water may be quite small near the ground surface; however, immediately after a rain the voids may be nearly filled. In their upper zone the natural water content wN and soil strength are transient phenomena. At nearly all points below the soil mantle there is a zone of flowing water called the water table. The soil below this point is saturated; however, individual samples may have trapped air bubbles and produce S slightly less than 100 percent. The water in this zone is flowing under a hydraulic gradient from a higher to lower energy level. The water level in a series of piezometers inserted along the direction of flow will define the hydraulic grade line. Above the water table is a capillary zone ($S \rightarrow$ 100 percent) where the voids are also nearly filled with water. This water is held in place by surface tension between water molecules and soil grains and is not free to move. The water in this zone produces an increase in the effective weight of the soil. The depth, of water below the water table produces a buoyant effect on the submerged soil.

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1. Introduction

Very considerable adverse effects on the soil can be produced by the pore pressure in the free water zone. Note, however, the water either in the capillary zone or from other sources may become a flow zone if the existing void ratio is sufficiently reduced that there is an excess of water for the remaining voids. Water cannot flow instantaneously; so any excess pore water will exist for some time under a higher energy potential (or pressure).

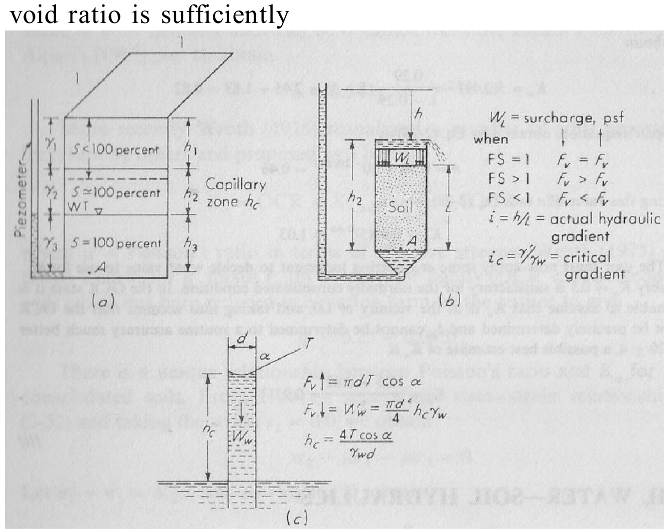

Figure 2-7 (a) Soil/water relationships for effective and pore-pressure concepts; (b) critical hydraulic gradient and concept of safety factor against a "quick" condition; (c) computation of height of capillary rise in a capillary tube.

2. Effective Pressure

The pore water (also called neutral) pressure reduces the total pressure on a plane to an effective value. Effective (or intergranular) pressure is defined as the pressure between the individual grains in a mass. This pressure and friction coefficient produces a portion of the shear strength of cohesive soils and all the shear strength of cohesionless soils. The nominal effective pressure is based on total load area since the actual grain contact area is indeterminate[1].

Referring to Fig. 2-7a and neglecting any shear resistance along the sides of the unit area, one can obtain the nominal effective pressure σ' at the surface of the water table as

$$\sigma' = \gamma_1 h_1 + \gamma_2 h_2 = q \qquad \text{psf or kN/m} \qquad \text{(a)}$$

Note that the capillary zone water directly affects γ_2 and "wet" unit weights are used for both γ_1 and γ_2.

The effective pressure at point A (below the water table) can be computed using Archimedes' principle as

$$\sigma' = q + \gamma_3 h_3 - \gamma_3 h_3 \qquad \text{(b)}$$

It is usual practice to define the submerged or buoyant unit weight $\gamma' = \gamma_{sat} - \gamma_w$, so that Eq. (b) with $\gamma_{sat} = \gamma_3$ is rewritten

$$\sigma' = q + \gamma' h_3 \quad \text{(c)}$$

We can obtain a general expression relating the effective pressure to the pore pressure using Eq. (b) and taking $\gamma_w h_3 = u$:

$$q + \gamma_3 h_3 = \sigma' + u \qquad \text{(d)}$$

$$\sigma = \sigma' + u$$

where the total pressure $\sigma = q + \gamma_3 h_3$.

Rearranging and solving for the effective stress,

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

Equation can be rewritten to include the effects of changes in u as

$$\sigma' = \sigma - (u + \Delta u)$$

Equation indicates that in increasing the neutral pressure (+ Δu) the effective pressure is decreased by the same amount. If the neutral pressure is sufficiently increased, the effective pressure reduces to zero; i.e., the soil will, if granular, possess no shear strength. This condition is referred to as a "quick" condition, and conditions for its occurrence may be approximately evaluated as follows.

From Fig. 2-7a, equating the upward and downward pressures at point A,

$$(h_2 - L)\gamma_w + L\gamma_{sat} + W_L (\text{downward}) = (h + h_2)\gamma_w$$

(upward) (e)

For F = 1 and with the surcharge $W_L = 0$ in Eq. (e) the hydraulic gradient

h/L is a critical value i_c. For this case

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

G_S for sand is approximately 2.65, and for the practical ranges in e from 0.3 to 1.0, i_c ranges from 0.8 to 1.25. Considering the several uncertainties involved, it is common to approximate $i_c = 1.0$.

3. Permeability

Flow of soil water, for nonturbulent conditions, has been expressed by Darcy as

$$v = ki$$

where i = hydraulic gradient h/L, as previously defined

k = coefficient of permeability as proposed by Darcy, length/time

Table 2-3 lists typical order-of-magnitude values for various soils. The quantity of flow q is

q = kiA volume/time

Two tests commonly used in the laboratory to determine k are the constanthead and falling-head methods. Figure 2-8 gives the schematic diagrams and the equations used for computing k. The falling-head test is usually used for $k < 10^{-5}$ m/s (cohesive soils) and the constant head for cohesionless soils.

Capillary Water

Capillary rise in a soil can be estimated from the equation for h_3 shown on Fig. 2-7a.

This equation generally overestimates the height of capillary rise considerably because the soil pore system is not regular. Few laboratory observations of capillary rise have been found to exceed 1 or 2 m.

Flow Nets

The flow of water through soil under an energy potential can be mathematically expressed by a Laplace equation as

$$k_x \frac{\partial^2 h}{\partial x^2} + k_y \frac{\partial^2 h}{\partial y^2} = 0$$

where k_X, k_y = coefficients of permeability parallel to the x, y axes, respectively h = energy potential

The above equation is for two-dimensional flow, which with appropriate axis rotation will apply to most seepage problems. A graphical solution of this equa', results in families of intersecting orthogonal curves which are called a flow net.

Table 2-3 Order-of-magnitude values for permeability k, based on description of soil and by Unified Classification, m/s

10^0 – 10^{-2}	10^{-2} – 10^{-5}	10^{-5} – 10^{-9}	10^{-9} – 10^{-11}
Clean gravel GW, GP	Clean gravel and sand mixtures GW, GP SW, SP GM	Sand-silt mixtures SM, SL, SC	Clays

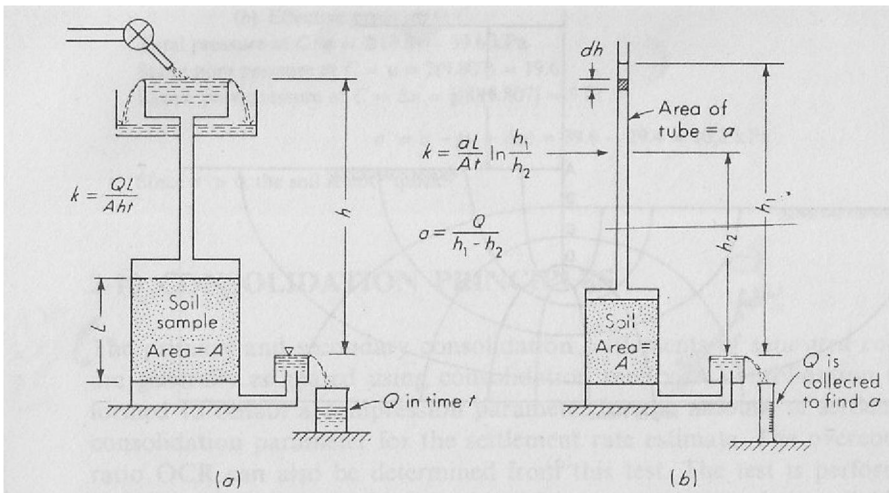

Figure 2-8 Schematic for permeability determination. (a) Constant-heat permeameter; (b) falling-heat permeameter.

One set of the curves represents equipotential lines (lines of constant piezometric head) and the other set intersecting at right angles represents flow paths. The flow net consists of squares of varying dimension if kx = ky and rectangles otherwise. In general, for reasonably homogeneous soil a graphical solution of the Laplace equation provides seepage quantities which are at least as correct as one is likely to obtain for the coefficients of permeability[2].

Seepage quantity from a flow net can be computed as

$$Q = kH \frac{n_f}{n_d} Wt \quad (ft^3 \text{ or } m^3 \text{ in time } t)$$

where k = transformed coefficient of permeability when $k_x \neq k_y$ and so the resulting flow net consists of squares, $k = \sqrt{k_X k_Y}$ in units of H and t

H = differential heat of fluid across system

N_f, n_d = numbers of flow paths and equipotential drops, respectively, in system

W = width of seepage flow

t = time base (1 hour, 1 day, 1 week, etc.)

Figure 2-9a illustrates a flow net for one side of a cofferdam-type structure which will be of most interest in this text. We may use the flow net to estimate how much drawdown may be allowed on the construction side of the wall or how much excavation can be performed before the construction side becomes "quick."

For other seepage problems the user is referred to any text on soil mechanics [e g., Wu (1976), Bowles (1979)].

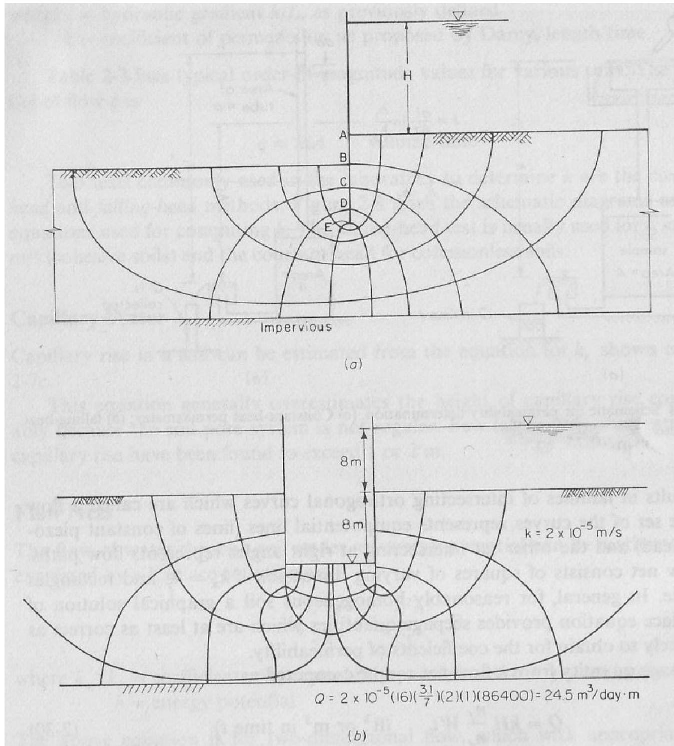

Figure 2-9 Typical flow nets as used for sheet-pile or cofferdam structures. (a) Single sheet-pile wall or other wall too far to influence net; (b) double-wall cofferdam -9§ used for bridge piers, etc.

Example 2-3 From Fig. 2-9a assume the following data:

H=6.0m k_x=k_Y=4x 10^{-5}m/s

ys,, = 19.80 kN/m3 (sand)

Distances: AB = 2 m, BC = 2 m, CD = 1.5 m, DE = 1 m

REQUIRED (a) Flow quantity/day per meter of wall (b) Effective pressure at point C

SOLUTION (a) Flow quantity(estimate n_f = 4.1).

Also with tailwater at thedredge line H=6+2=8m.

$$Q = KH\frac{n_f}{n_d}wt = 4\times10^{-5}(8)\left(\frac{4.1}{8}\right)(1)(86\,400) = 14.2\,m^3/day$$

4. Conclusion

In Foundation design always study and be sure about the complete compact of soil shat are used in the project.

Refrence

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