Geotechnical Engineering–I

BSc Civil Engineering – 4th Semester

Lecture # 23

27-Apr-2015

by

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Lecture Handouts: https://groups.google.com/d/forum/geotec-1

WATER FLOW THROUGH SOILS

$$q = k \cdot i \cdot A = k \cdot \frac{\Delta h}{L} \cdot A$$

To determine the quantity of flow, two parameters are needed

* k = hydraulic conductivity *(how permeable is the soil medium)*

* i = hydraulic gradient *(how large is the driving head)*

Determination of *'k'*

1- Laboratory Testing → [constant head test & falling head test]

2- Field Testing → [pumping from wells]

3- Empirical Equations

Today's discussion

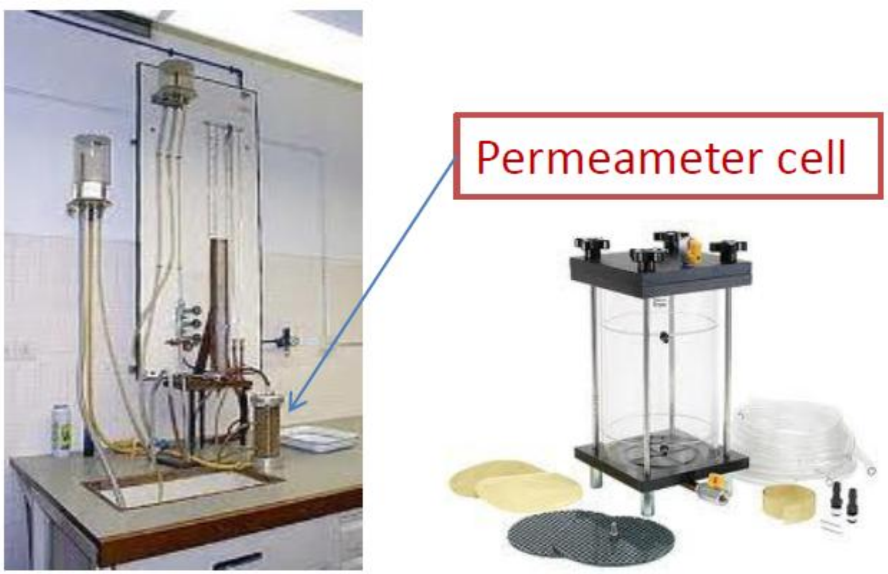
Determination of *'i'*

1- from the head loss and geometry

2- flow nets

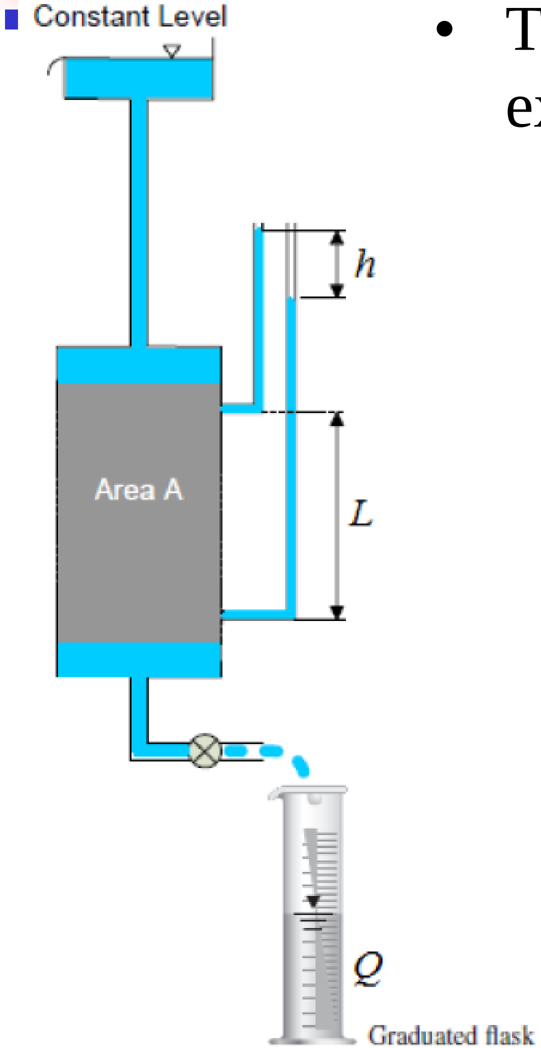
CONSTANT HEAD PERMEABILITY TEST
(ASTM D2434)

- Primarily used for *coarse-grained soils*.
- A *constant head of water* is applied to each end of soil in a "permeameter".
- After a *constant flow rate* is established, water is collected in a graduated flask for a known duration.



CONSTANT HEAD PERMEABILITY TEST

(ASTM D2434)



- The total volume of collected water may be expressed as;

$$Q = Avt = A\left(ki\right)t$$

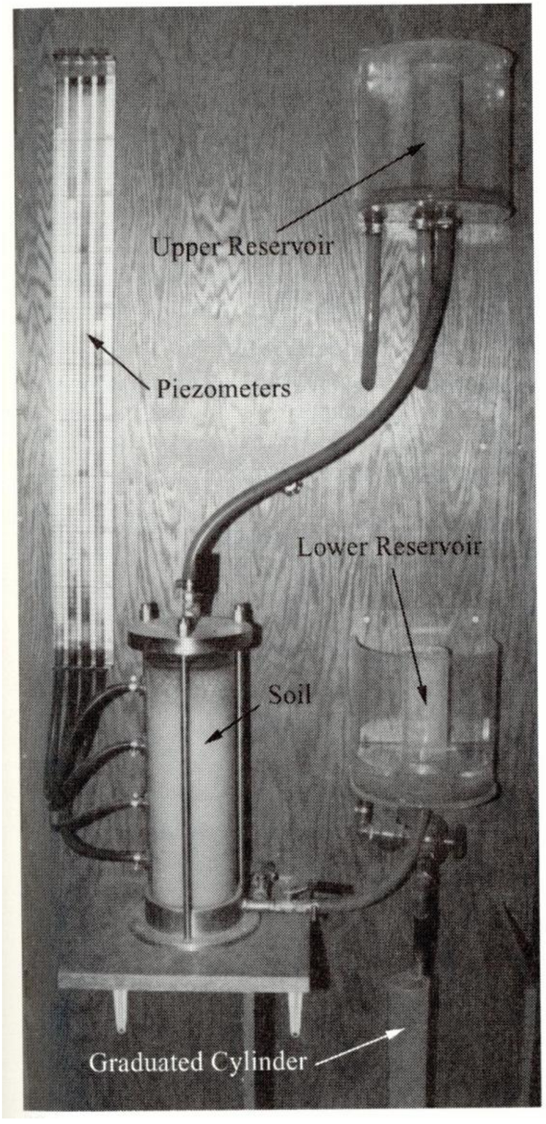
$$i = \frac{h}{L} \qquad Q = A\left(k\frac{h}{L}\right)t$$

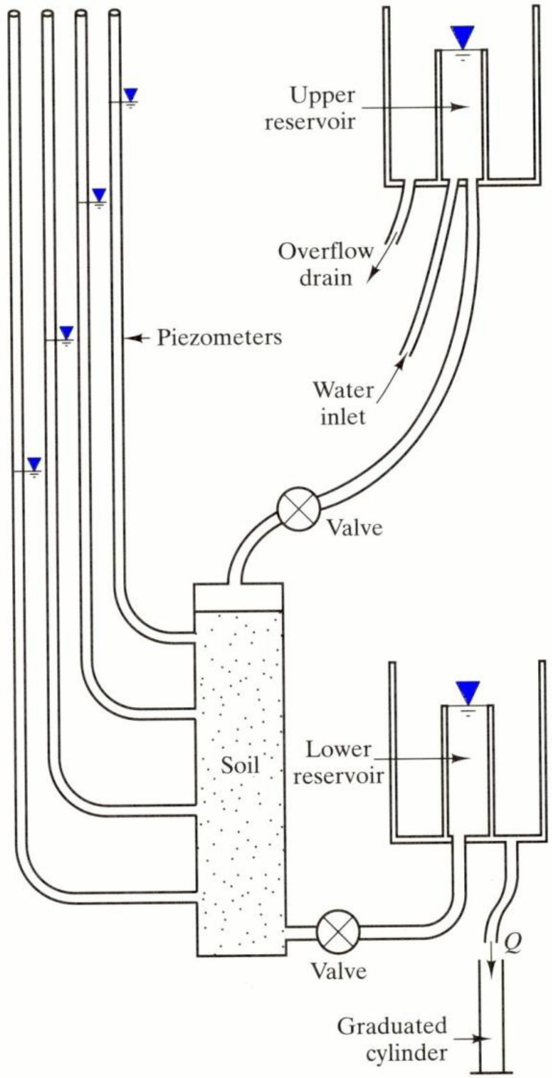
$$k = \frac{QL}{Aht}$$

Q = volume of water collected
A = x-sec area of soil specimen
t = duration of water collection

CONSTANT HEAD PERMEABILITY TEST

(ASTM D2434)



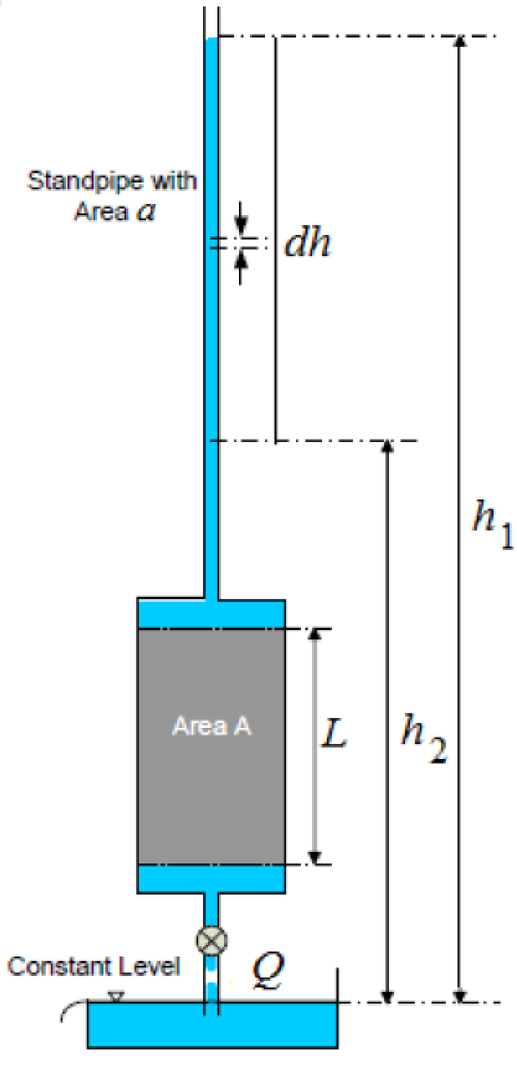


$$k = \frac{QL}{Aht}$$

$$k_{20^0 C} = k_{T^0 C} \frac{\eta_{T^0 C}}{\eta_{20^0 C}}$$

FALLING/VARIABLE HEAD PERMEABILITY TEST

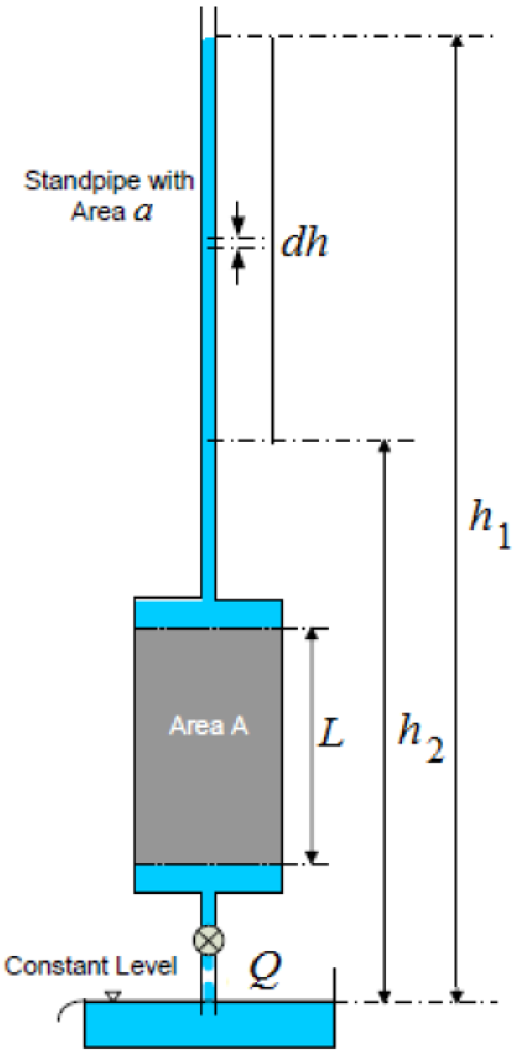
(ASTM D5084)



- Mainly used for *fine-grained soils* but can also be used for coarse-grained soils.
- Procedure is same as constant head test except:
    - Record *initial head difference*, h_1 at $t=0$.
    - Allow water to flow through the soil specimen.
    - Record the *final head difference*, h_2 at $t=t_2$.
    - Record the *volume of water*, Q (in ml), collected at the outlet during this time.

FALLING/VARIABLE HEAD PERMEABILITY TEST

(ASTM D5084)



- Rate of flow of water through the specimen at any time '*t*' can be given by;

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

q: rate of flow

a: cross sectional area of standpipe

A: cross sectional area of the soil sample

$$dt = \frac{aL}{Ak}\left(-\frac{dh}{h}\right) \Rightarrow \int_0^{t_1} dt = -\frac{aL}{Ak}\int_{h_2}^{h_1}\frac{dh}{h}$$

$$\Downarrow$$

$$k = \frac{aL}{At}\ln\frac{h_1}{h_2} \Leftarrow t = \frac{aL}{Ak}\ln\frac{h_1}{h_2}$$

$$k = 2.303\frac{aL}{At}\log\frac{h_1}{h_2}$$

h_1 = head at the start of test

h_2 = head at the end of test

Practice Problem #1

A constant head permeability test on a medium sand sample having a x-sectional area of $7585 mm^2$ yielded the following data.

Distance between stand pipes = 100 mm
Constant head difference = 70.4 mm
Quantity of water collected = 500×10^3 mm^3
Time of collection = 132 sec

Determine the coefficient of permeability of sand specimen.

Practice Problem #2

In a falling head permeability test, a soil sample of 7585mm^2 cross-section and 210.2mm length was subjected to a flow of water from a stand-pipe having cross-sectional area of 730mm^2. The stand-pipe level changed from 1650mm to 550mm above reservoir datum during a time interval of 182sec. Determine the coefficient of permeability of soil.

Practice Problem #3

A constant head permeameter, 85 mm in diameter containing a fine sand sample 450mm long, allowed water to flow at a rate of 184ml/min under steady-flow conditions. Given the difference in head between two points 240mm apart was 375mm, determine the coefficient of permeability in mm/sec. When the same size sample is tested in a falling head apparatus using a stand-pipe of 32.5mm diameter. Calculate the time required for the water in the stand-pipe to drop from 1750mm to 1000mm above outflow level to the nearest five seconds.

DETERMINATION OF '*k*' – EMPIRICAL EQUATIONS

Allen Hazen's Method

Permeability of filter sands

$$\boldsymbol{k = C \cdot (D_{10})^2}$$

k = coefficient of permeability (cm/sec)

C = empirical coefficient varying from 90 to 120; typically assumed as 100

D_{10} = effective size in cm

Applicability → $k > 10^{-3}$ cm/sec

D_{10} ranging from 0.1 mm – 3 mm

$Cu < 5$

Permeability from Consolidation Test

$$\boldsymbol{k = C_V \cdot m_V \cdot \gamma_w}$$

Applicability → Clays with $k \leq 10^{-7}$ cm/sec

DEPENDENCE OF HYDRAULIC CONDUCTIVITY *(k)*

1- Effect of Shape and Size of Particles

$k = C \,.\, (D_{10})^2$ Allen Hazen's equation

i.e., coarser the soil, larger would be permeability

2- Effect of Void Ratio

For sands, the following two equations hold good.

$$\frac{k_1}{k_2} = \frac{e_1^{\,2}}{e_2^{\,2}} \qquad \text{OR} \qquad \frac{k_1}{k_2} = \frac{e_1^{\,3}}{1+e_1} \cdot \frac{1+e_2}{e_2^{\,3}}$$

i.e., larger the void ratio, greater would be permeability

DEPENDENCE OF HYDRAULIC CONDUCTIVITY *(k)*

3- Effect of Stratification

Permeability *parallel* to the strata > permeability *perpendicular* to the strata

4- Effect of Degree of Saturation

Sample for permeability test → *fully saturated*.

Low degree of saturation → low permeability; because entrapped air blocks water flow

5- Effect of Temperature

Temperature affects viscosity and density of pore fluid

Higher the temperature, higher will be permeability.

Lab tests are standardized at 20°C

$$k_{20^0 C} = k_{T^0 C} \frac{\eta_{T^0 C}}{\eta_{20^0 C}}$$

CONCLUDED