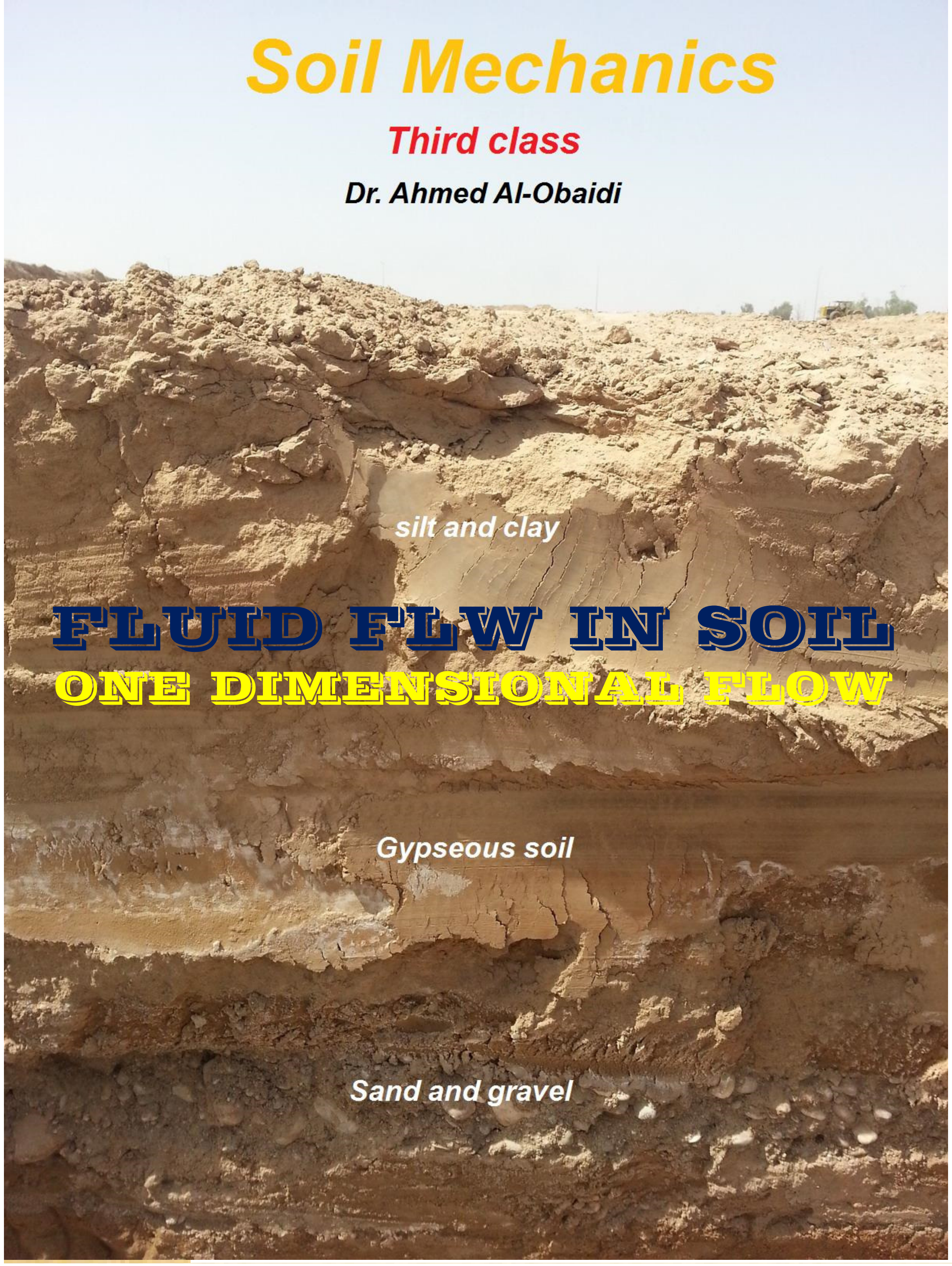


Tikrit University

College of Engineering

Civil engineering Department

Soil Mechanics

3rd Class

Lecture notes

One Dimensional Flow

Soil is a three phase medium -------- solids, water, and air

**** Water in soils occur in various conditions***

**** Water can flow through the voids in a soil from a point of high energy to a point of low energy.***

**** Why studying flow of water in porous media ???????***

1- To estimate the quantity of underground seepage

2- To determine the quantity of water that can be discharged form a soil

3- To determine the pore water pressure/effective geostatic stresses, and to analyze earth structures subjected to water flow.

4- To determine the volume change in soil layers (soil consolidation) and settlement of foundation.

One Dimensional Flow

** Flow of Water in Soils depends on:*

1- Porosity of the soil

2- Type of the soil - particle size - particle shape - degree of packing

3- Viscosity of the fluid – Temperature - Chemical Components

4- Total head (difference in energy) - Pressure head - Velocity head

One Dimensional Flow

- Elevation head

The degree of compressibility of a soil is expressed by the coefficient of permeability of the soil "k.“

k cm/sec, ft/sec, m/sec, ...

Hydraulic Gradient

Bernouli's Equation

$$h = Z + \frac{P}{\gamma_w} + \frac{v^2}{2g}$$

For soil

$$h = Z + \frac{P}{\gamma_w} + \frac{v^2}{2g}$$

One Dimensional Flow

Flow of Water in Soils

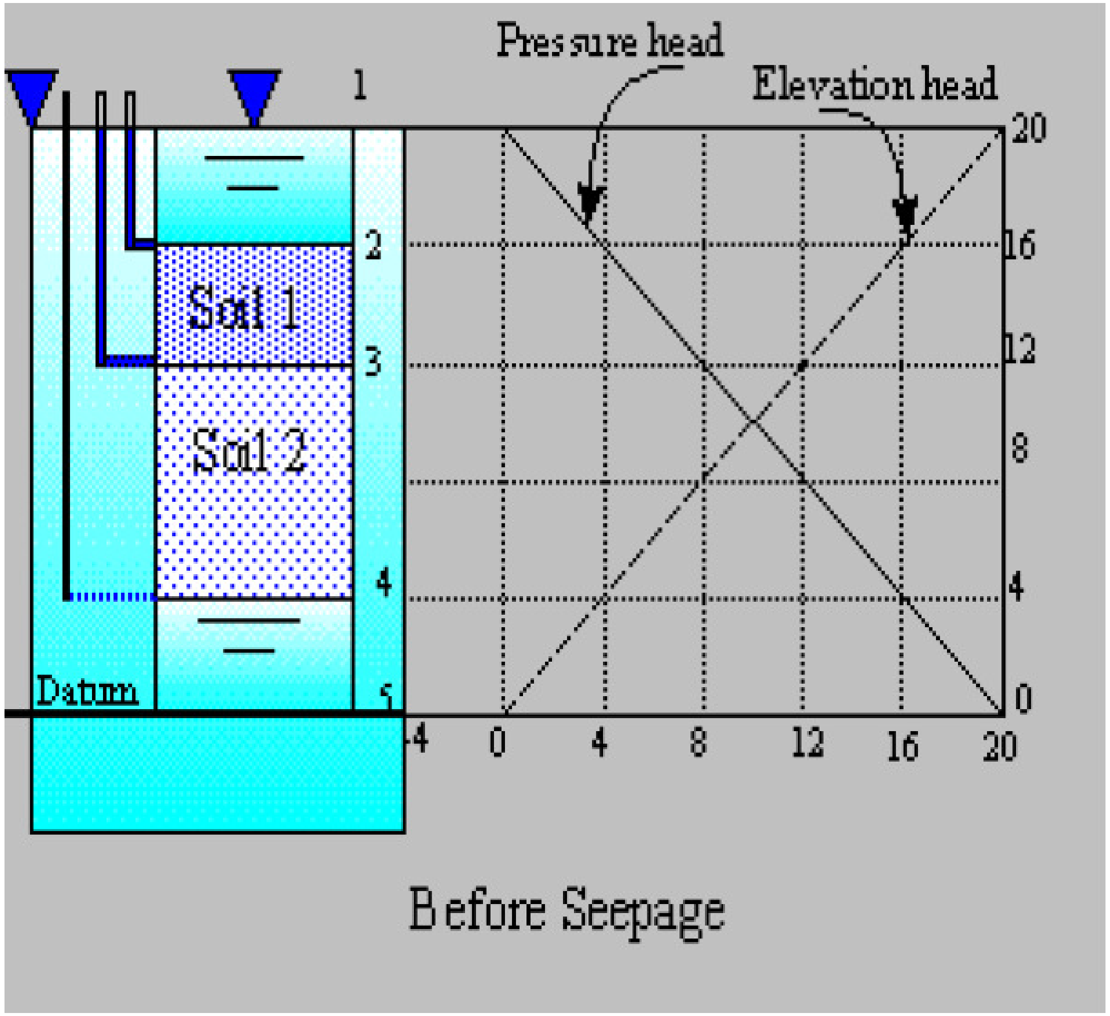
1- Hydraulic Head in Soil

Total Head = Pressure head + Elevation Head

ht = hp + he

- ***Elevation head at a point = Extent of that point from the datum***
- ***Pressure head at a point = Height of which the water rises in the piezometer above the point.***
- ***Pore Water pressure at a point = P.W.P. = gwater . hp***

One Dimensional Flow



One Dimensional Flow

How to measure the Pressure Head or the Piezometric Head????????

Tips

1- Assume that you do not have seepage in the system (Before Seepage)

2- Assume that you have piezometer at the point under consideration

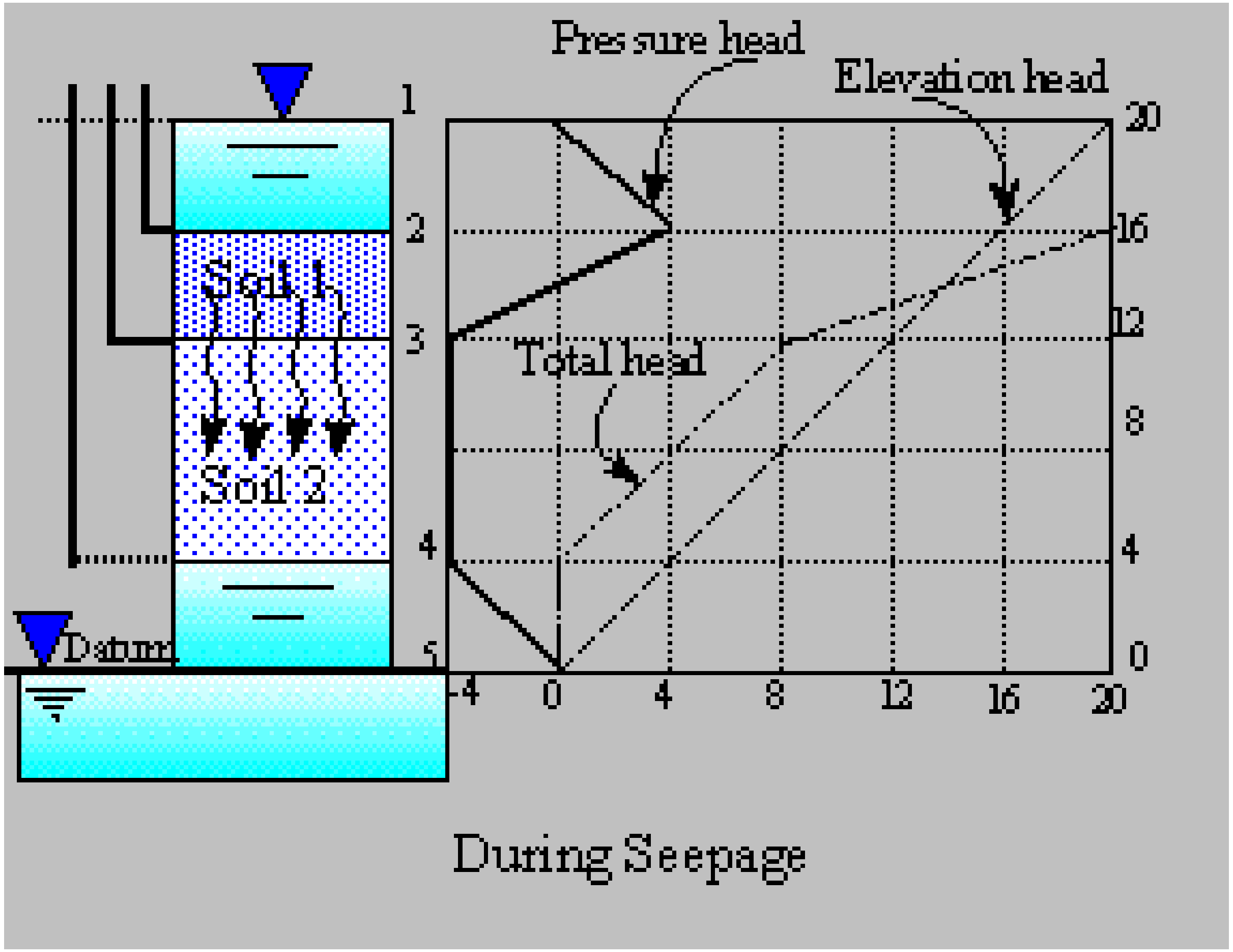
3- Get the measurement of the piezometric head (Water column in the Piezometer before seepage) = hp(Before Seepage)

4- Now consider the problem during seepage

5- Measure the amount of the head loss in the piezometer (Dh) or the drop in the piezometric head.

6- The piezometric head during seepage = hp(during seepage) = hp(Before Seepage) - Dh

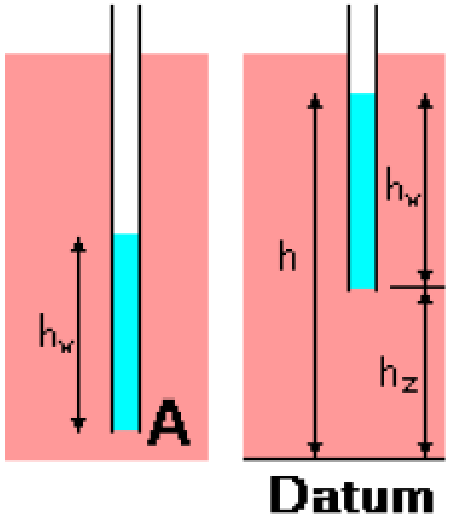
One Dimensional Flow



One Dimensional Flow

Pressure, Elevation and Total Heads

In soils, the interconnected pores provide passage for water. A large number of such flow paths act together, and the average rate of flow is termed the coefficient of permeability, or just permeability. It is a measure of the ease that the soil provides to the flow of water through its pores.



One Dimensional Flow

At point **A, the pore water pressure (u) can be measured from the height of water in a standpipe located at that point.**

The height of the water column is the pressure head (hw).

hw = u/gw

To identify any difference in pore water pressure at different points, it is necessary to eliminate the effect of the points of measurement. With this in view, a datum is required from which locations are measured.

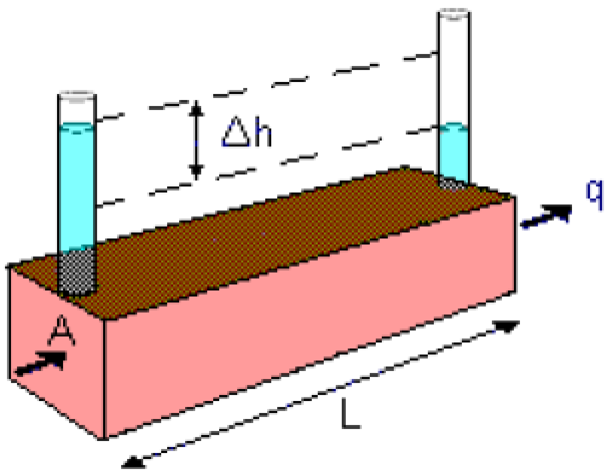
One Dimensional Flow

- The **elevation head**
- **(hz) of any point is its height above the datum line. The height of water level in the standpipe above the datum is the piezometric head (h).**
- **h = hz + hw**
- **Total head consists of *three components: elevation head, pressure head, and velocity head. As seepage velocity in soils is normally low, velocity head is ignored, and total head becomes equal to the piezometric head. Due to the low seepage velocity and small size of pores, the flow of water in the pores is steady and laminar in most cases. Water flow takes place between two points in soil due to the difference in total heads.***

One Dimensional Flow

Darcy's Law

Darcy's law states that there is a linear relationship between flow velocity (v) and hydraulic gradient (i) for any given saturated soil under steady laminar flow conditions.



One Dimensional Flow

If the rate of flow is **q (volume/time) through cross-sectional area (A) of the soil mass, Darcy's Law can be expressed as**

v = q/A = k.i

where

k = permeability of the soil

i = Dh/L

‘Dh = difference in total heads

L = length of the soil mass

One Dimensional Flow

The flow velocity (**v**) **is also called the Darcian velocity or the superficial velocity. It is different from the actual velocity inside the soil pores, which is known as the seepage velocity, vS. At the particulate level, the water follows a tortuous path through the pores. Seepage velocity is always greater than the superficial velocity, and it is expressed as:**

$$v_s = \frac{q}{A_v} = \frac{q}{A_v} \cdot \frac{A}{A} \approx \frac{v}{n}$$

One Dimensional Flow

Permeability of Different

Soils Permeability (k) is an engineering property of soils and is a function of the soil type. Its value depends on the average size of the pores and is related to the distribution of particle sizes, particle shape and soil structure. The ratio of permeabilities of typical sands/gravels to those of typical clays is of the order of 106. A small proportion of fine material in a coarse-grained soil can lead to a significant reduction in permeability

One Dimensional Flow

For different soil types as per grain size, the orders of magnitude for permeability are as follows:

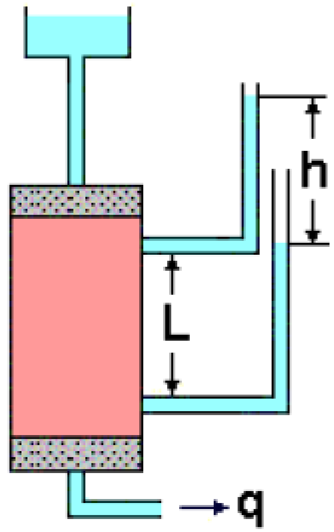
Soil	k (cm/sec)
Gravel	10^{0}
Coarse sand	10^{0} to 10^{-1}
Medium sand	10^{-1} to 10^{-2}
Fine sand	10^{-2} to 10^{-3}
Silty sand	10^{-3} to 10^{-4}
Silt	1×10^{-5}
Clay	10^{-7} to 10^{-9}

One Dimensional Flow

Laboratory Measurement of Permeability

Constant Head Flow

Constant head permeameter is recommended for coarse-grained soils only since for such soils, flow rate is measurable with adequate precision. As water flows through a sample of cross-section area A, steady total head drop h is measured across length L.

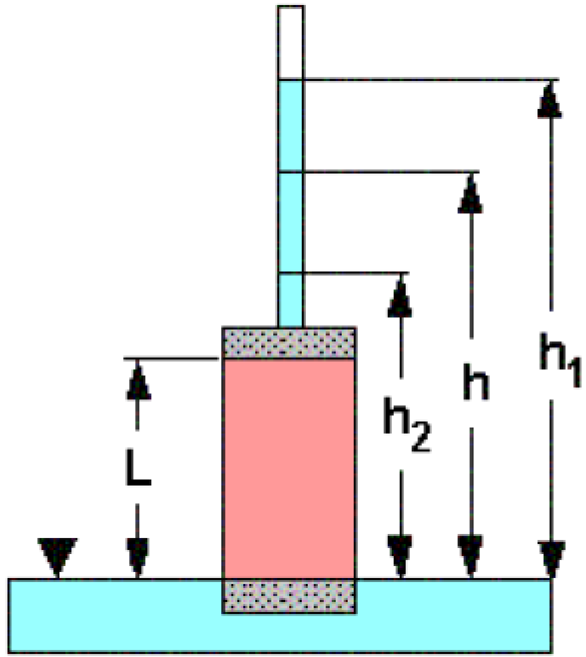


Permeability **k is obtained from:**

$$k = \frac{qL}{Ah}$$

One Dimensional Flow

Falling Head Flow Falling head permeameter is recommended for fine-grained soils.



One Dimensional Flow

Total head **h in standpipe of area a is allowed to fall. Hydraulic gradient varies with time. Heads h1 and h2 are measured at times t1 and t2. At any time t, flow through the soil sample of cross-sectional area A is**

$$q = k.h.\frac{A}{L} \quad \text{--------------------} \quad (1)$$

Flow in unit time through the standpipe of cross-sectional area **a is**

One Dimensional Flow

$$= a \times \left(-\frac{dh}{dt} \right) \text{-----------------} (2)$$

Equating **(1)** and **(2)** ,

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

or $$-\frac{dh}{h} = \left(\frac{kA}{La} \right) dt$$

Integrating between the limits,

$$\log_e \left(\frac{h_1}{h_2} \right) = \frac{k.A}{L.a} (t_2 - t_1)$$

$$k = \frac{L.a.\log_e \left(\frac{h_1}{h_2} \right)}{A(t_2 - t_1)}$$

$$= \frac{2.3L.a\log_{10} \left(\frac{h_1}{h_2} \right)}{A(t_2 - t_1)}$$

One Dimensional Flow

Examples