Geotechnical Engineering–I

BSc Civil Engineering – 4th Semester

Lecture # 25

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by

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

Equivalent Hydraulic Conductivity of Stratified Soils

Permeability Parallel to Stratification

- Velocity of flow ‘v’ → different for all layers
- Hydraulic gradient ‘i’ → same for each layer.

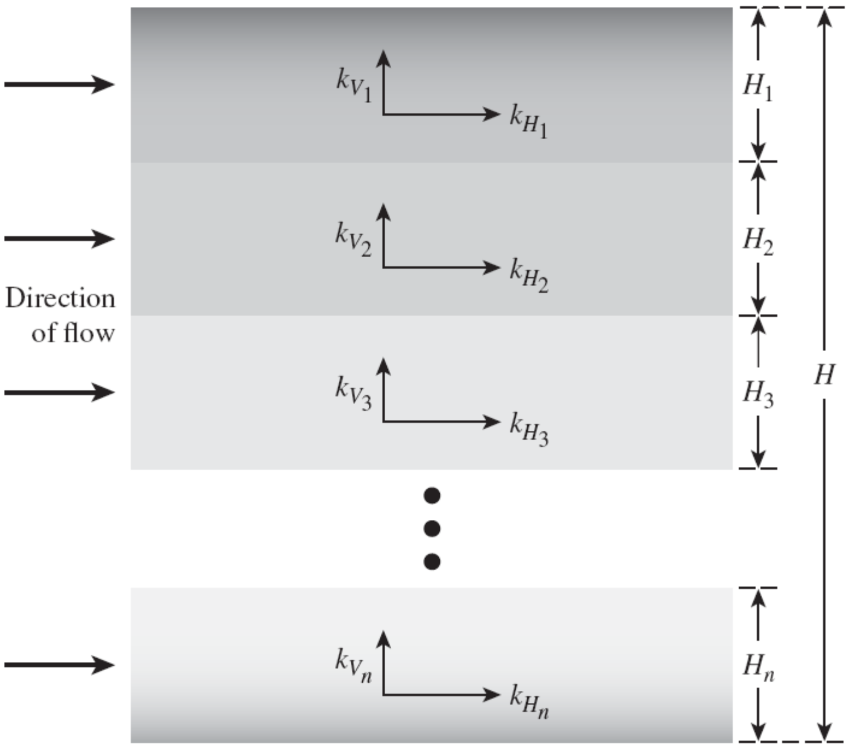
$$q = k_H \cdot i \cdot H$$

Total flow → sum of flows though each layer

$$q = k_{H1} \cdot i \cdot H_1 + k_{H2} \cdot i \cdot H_2 + k_{H3} \cdot i \cdot H_3 + \cdots + k_{Hn} \cdot i \cdot H_n$$

$$k_H \cdot i \cdot H = k_{H1} \cdot i \cdot H_1 + k_{H2} \cdot i \cdot H_2 + k_{H3} \cdot i \cdot H_3 + \cdots + k_{Hn} \cdot i \cdot H_n$$

$$k_H = \frac{k_{H1} \cdot H_1 + k_{H2} \cdot H_2 + k_{H3} \cdot H_3 + \cdots + k_{Hn} \cdot H_n}{H}$$



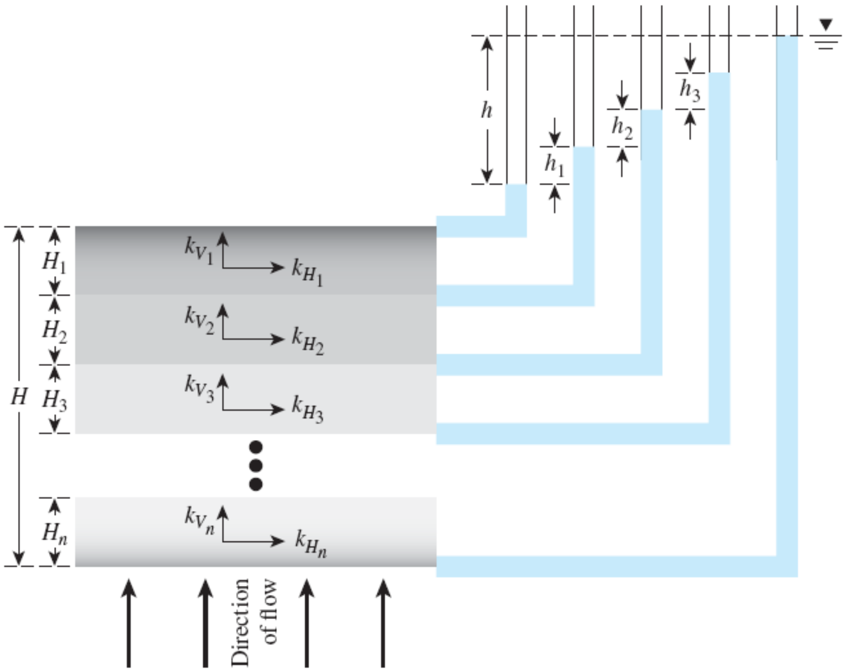
Equivalent Hydraulic Conductivity of Stratified Soils

Permeability Perpendicular to Stratification

- Velocity of flow *'v'* and discharge *'q'* → same through each layer
- Hydraulic gradient *'i'* and head loss *'h'* → different through each layer.

$$h = h_1 + h_2 + h_3 + \cdots h_n \qquad i = \frac{h}{H}$$

$$h = i_1 \cdot H_1 + i_2 \cdot H_2 + i_3 \cdot H_3 + \cdots i_n \cdot H_n \quad \cdots (1)$$



k_v = average permeability perpendicular to stratification

$$v = k_v \cdot i = k_v \cdot \frac{h}{H} \quad \Rightarrow \quad h = \frac{v \cdot H}{k_v}$$

Also,

$$i_1 = \frac{v}{k_{v1}} \qquad i_2 = \frac{v}{k_{v2}} \qquad i_3 = \frac{v}{k_{v3}}$$

Replacing in eq. (1)

$$\frac{v \cdot H}{k_V} = \frac{v \cdot H_1}{k_{V1}} + \frac{v \cdot H_2}{k_{V2}} + \frac{v \cdot H_3}{k_{V3}} + \cdots + \frac{v \cdot H_n}{k_{Vn}}$$

$$k_V = \frac{H}{\frac{H_1}{k_{V1}} + \frac{H_2}{k_{V2}} + \frac{H_3}{k_{V3}} + \cdots + \frac{H_n}{k_{Vn}}}$$

Practice Problem #4

On close investigation of a sample it was found to be in three layers 20mm, 60mm, and 40mm. The permeability of these layers are 3×10^{-3}mm/sec, 5×10^{-4}mm/sec, and 17×10^{-4}mm/sec respectively. Find k_H and k_V, and the ratio k_H/k_V.

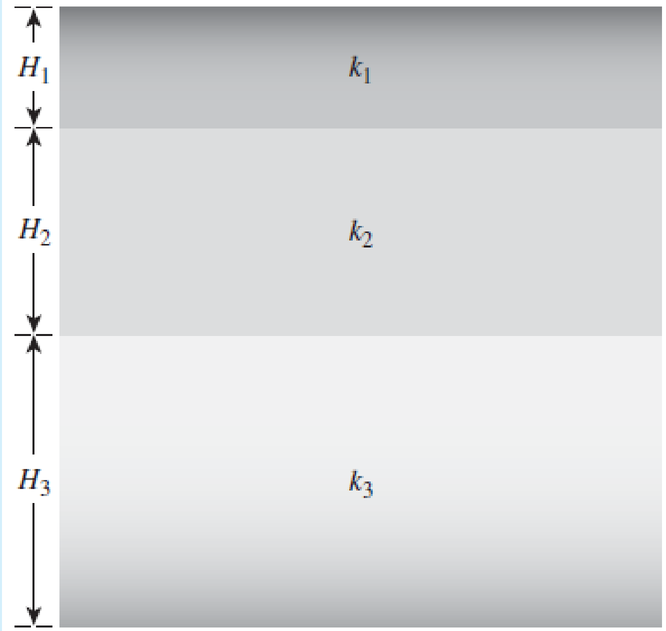
Practice Problem #5

A layered soil is shown in Figure 7.19. Given:

- $H_1 = 2$ m $\quad k_1 = 10^{-4}$ cm/sec
- $H_2 = 3$ m $\quad k_2 = 3.2 \times 10^{-2}$ cm/sec
- $H_3 = 4$ m $\quad k_3 = 4.1 \times 10^{-5}$ cm/sec

Estimate the ratio of equivalent hydraulic conductivity,

$$\frac{k_{H(\text{eq})}}{k_{V(\text{eq})}}$$



Practice Problem #5

Solution

From Eq. (7.40),

$$k_{H(\mathrm{eq})} = \frac{1}{H}(k_{H_1}H_1 + k_{H_2}H_2 + k_{H_3}H_3)$$

$$= \frac{1}{(2+3+4)}[(10^{-4})(2) + (3.2 \times 10^{-2})(3) + (4.1 \times 10^{-5})(4)]$$

$$= 107.07 \times 10^{-4}\ \mathrm{cm/sec}$$

Again, from Eq. (7.45),

$$k_{V(\mathrm{eq})} = \frac{H}{\left(\frac{H_1}{k_{V_1}}\right) + \left(\frac{H_2}{k_{V_2}}\right) + \left(\frac{H_3}{k_{V_3}}\right)}$$

$$= \frac{2+3+4}{\left(\frac{2}{10^{-4}}\right) + \left(\frac{3}{3.2 \times 10^{-2}}\right) + \left(\frac{4}{4.1 \times 10^{-5}}\right)}$$

$$= 0.765 \times 10^{-4}\ \mathrm{cm/sec}$$

Hence,

$$\frac{k_{H(\mathrm{eq})}}{k_{V(\mathrm{eq})}} = \frac{107.07 \times 10^{-4}}{0.765 \times 10^{-4}} = \mathbf{139.96}$$

Practice Problem #6

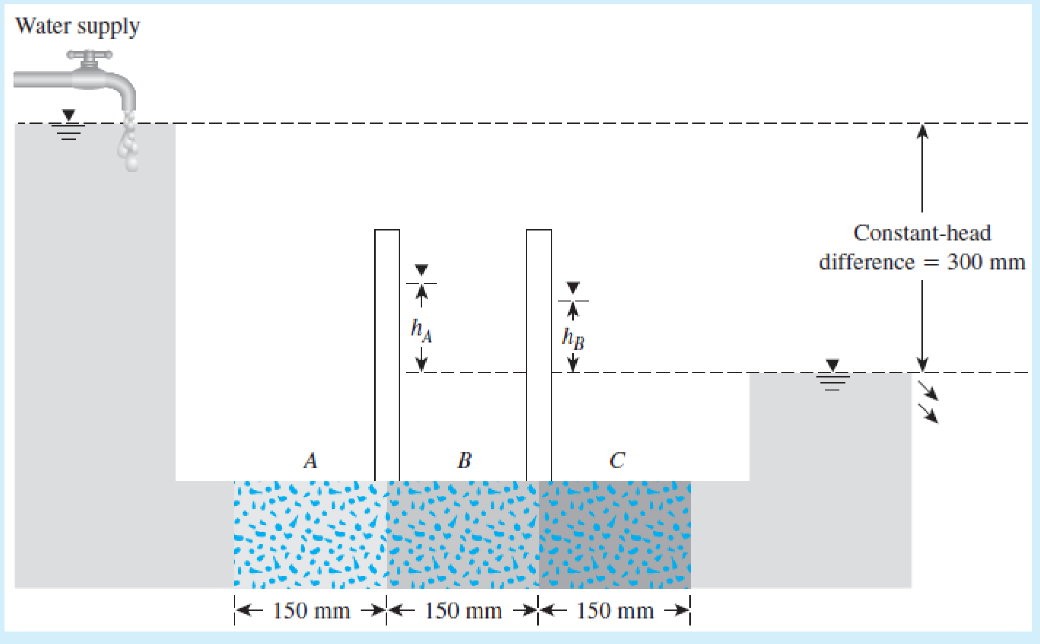


Figure 7.20 Three layers of soil in a tube 100 mm × 100 mm in cross section

Figure 7.20 shows three layers of soil in a tube that is 100 mm × 100 mm in cross section. Water is supplied to maintain a constant-head difference of 300 mm across the sample. The hydraulic conductivities of the soils in the direction of flow through them are as follows:

Soil	*k* (cm /sec)
A	10^{-2}
B	3×10^{-3}
C	4.9×10^{-4}

Find the rate of water supply in cm^3/hr.

Practice Problem #6

Solution

From Eq. (7.45),

$$k_{V(eq)} = \frac{H}{\left(\frac{H_1}{k_1}\right) + \left(\frac{H_2}{k_2}\right) + \left(\frac{H_3}{k_3}\right)} = \frac{450}{\left(\frac{150}{10^{-2}}\right) + \left(\frac{150}{3 \times 10^{-3}}\right) + \left(\frac{150}{4.9 \times 10^{-4}}\right)}$$

$$= 0.001213 \text{ cm/sec}$$

$$q = k_{V(eq)} i A = (0.001213)\left(\frac{300}{450}\right)\left(\frac{100}{10} \times \frac{100}{10}\right)$$

$$= 0.0809 \text{ cm}^3\text{/sec} = \mathbf{291.24\ cm^3/hr}$$

SIGNIFICANCE OF SEEPAGE STUDIES

Failure of Tenton Dam

- **Newly completed Teton Dam** as it appeared in mid May 1976, as the reservoir was filling at the rate of 3 feet per day. The *rate of filling is usually limited to no more than 1 foot per day*.

TENTON DAM FAILURE

Leakage was initially noted around 7:00 AM on Saturday June 5, 1976. This view shows a dozer being sent down to fill in the hole at elevation 5200 around 10:45 AM.

TENTON DAM FAILURE

The dozer is lost in the expanding hole, around 11:20 AM on June 5th. Note turbid nature of outflow along the abutment.

TENTON DAM FAILURE

Rapidly deteriorating situation as it appeared around 11:30 AM. A massive hole has developed in the downstream face of the embankment and is migrating upward.

TENTON DAM FAILURE

The hole continues to enlarge and rise toward the crest of the right abutment. This is about 11:50 AM.

TENTON DAM FAILURE

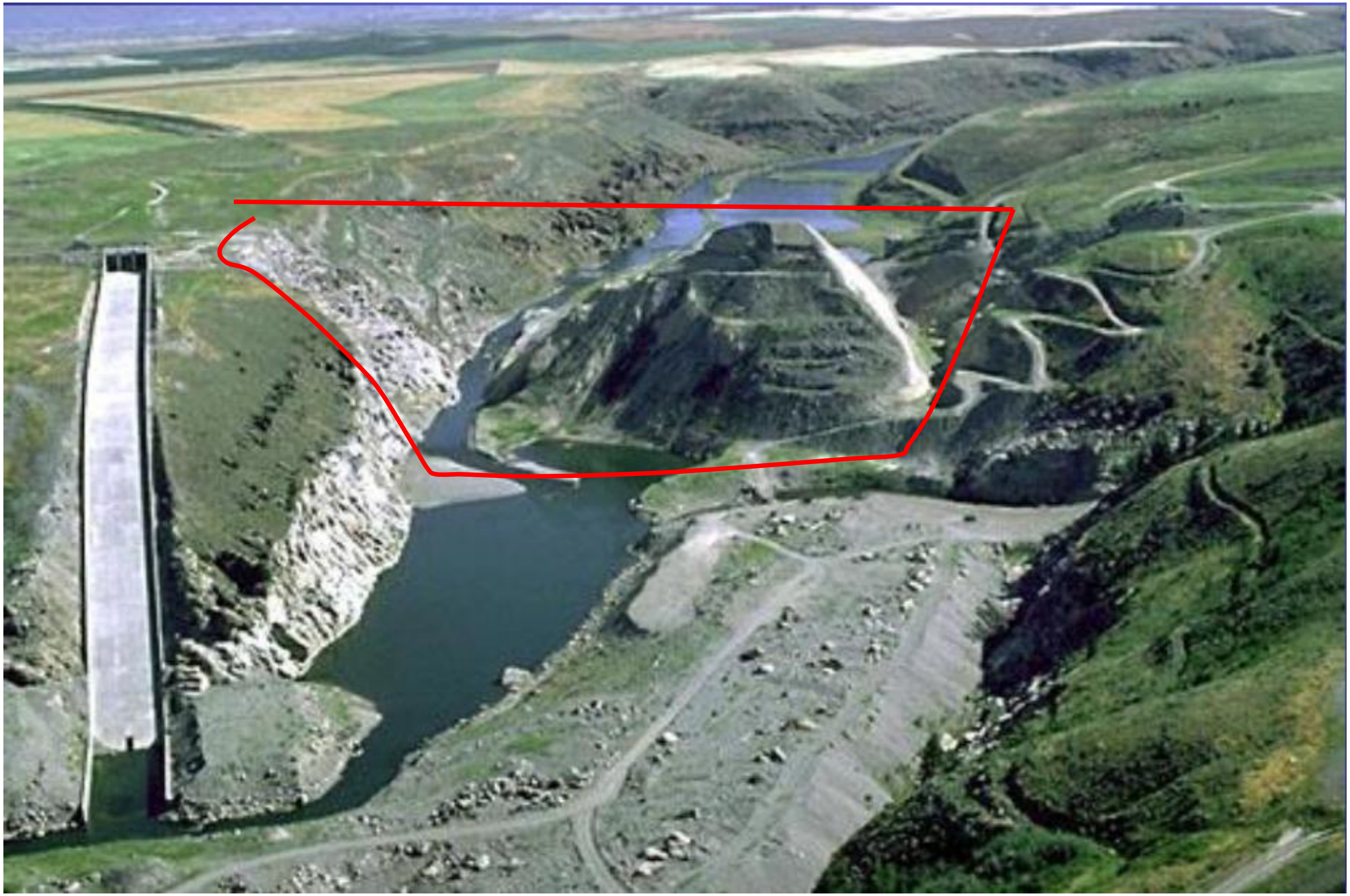
Dam crest beginning to breach at 11:55 AM on Saturday June 5, 1976. Note increasing discharge.

TENTON DAM FAILURE

Maximum flood discharge emanating from gap in dam's right abutment, just after noon on June 5th , 1976.

TENTON DAM FAILURE

Present day situation



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