Permeability

Soil Mechanic I

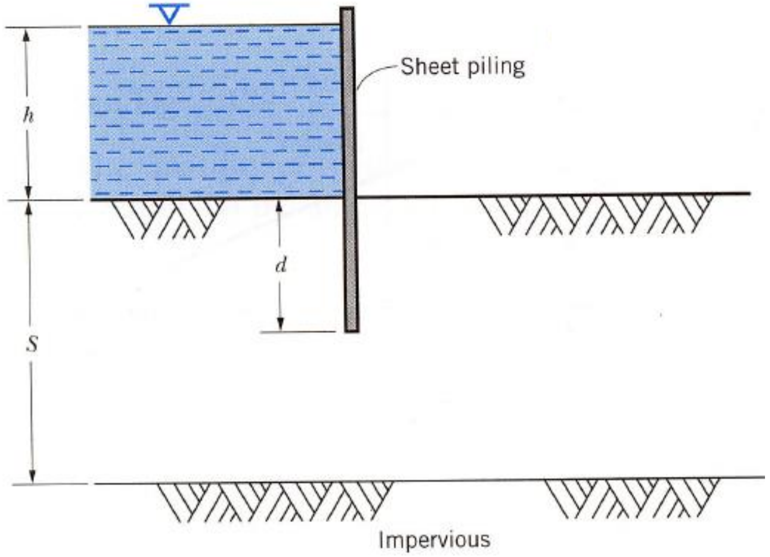
Sherly Meiwa , ST., MT

Department of Civil Engineering
Universitas Komputer Indonesia
Bandung, 2020

Tujuan Pembelajaran

Penting untuk mengetahui kuantitas rembesan air dalam tanah pada berbagai kondisi hidraulik tanah untuk beberapa penerapan dalam pekerjaan Teknik sipil :

1. Kebutuhan alat pompa air pada konstruksi
2. Anilisis kestabilan struktur bending dan bendungan
3. Analisis kestabilan struktur dinding penahan akibat adanya gaya rembesan



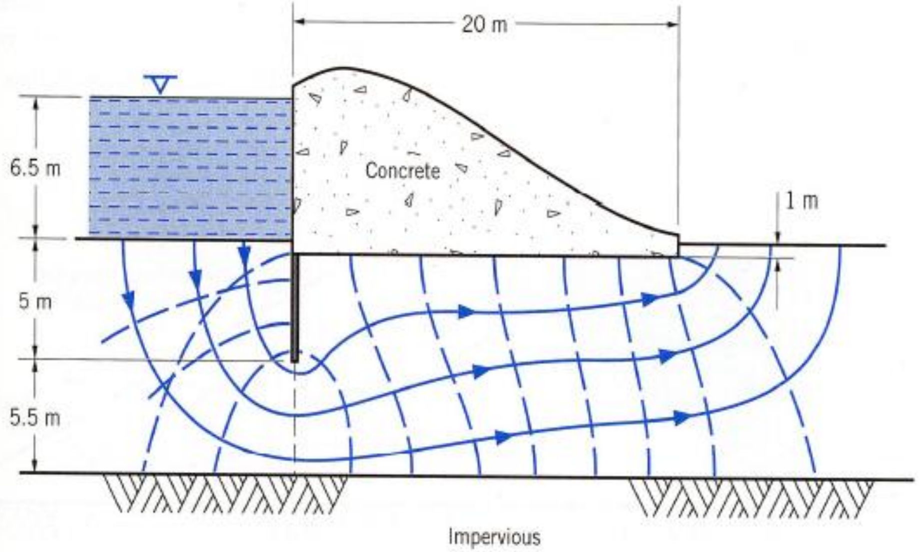


Figure 7.10 Flow net for a concrete dam with cutoff wall.

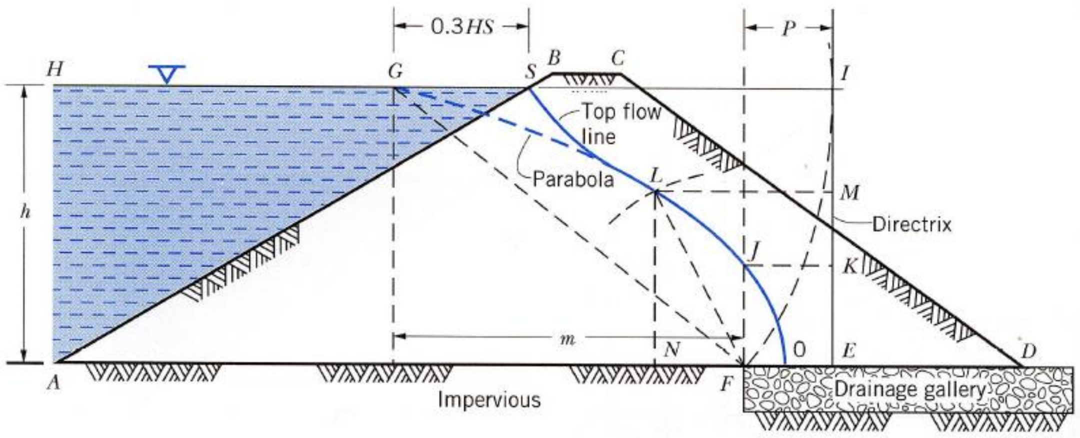


Figure 7.14 Development of top flow line from parabola.

Rumus Bernoulli

$$h = \underset{\substack{\uparrow \\ \text{Pressure} \\ \text{head}}}{\frac{u}{\gamma_w}} + \underset{\substack{\uparrow \\ \text{Velocity} \\ \text{head}}}{\frac{v^2}{2g}} + \underset{\substack{\uparrow \\ \text{Elevation} \\ \text{head}}}{Z}$$

where h = total head
u = pressure
v = velocity
g = acceleration due to gravity
γ_w = unit weight of water

Air mengalir dari energi yang tinggi menuju energi yang rendah. Berdasarkan rumus Bernoulli, Total head adalah penjumlahan dari pressure head, velocity head, dan elevasi head.

Air yang mengalir melalui pori-pori tanah. Untuk menghitung besar perbedaan energi dari suatu titik datum. Kecepatan aliran air sangat kecil sehingga nilai velocity head bisa diabaikan pada perhitungan ini

$$h = \underset{\substack{\uparrow \\ \text{Pressure} \\ \text{head}}}{\frac{u}{\gamma_w}} + \underset{\substack{\uparrow \\ \text{Velocity} \\ \text{head}}}{\cancel{\frac{v^2}{2g}}} + \underset{\substack{\uparrow \\ \text{Elevation} \\ \text{head}}}{Z}$$

$$h = \frac{u}{\gamma_w} + Z$$

Rumus Bernoulli

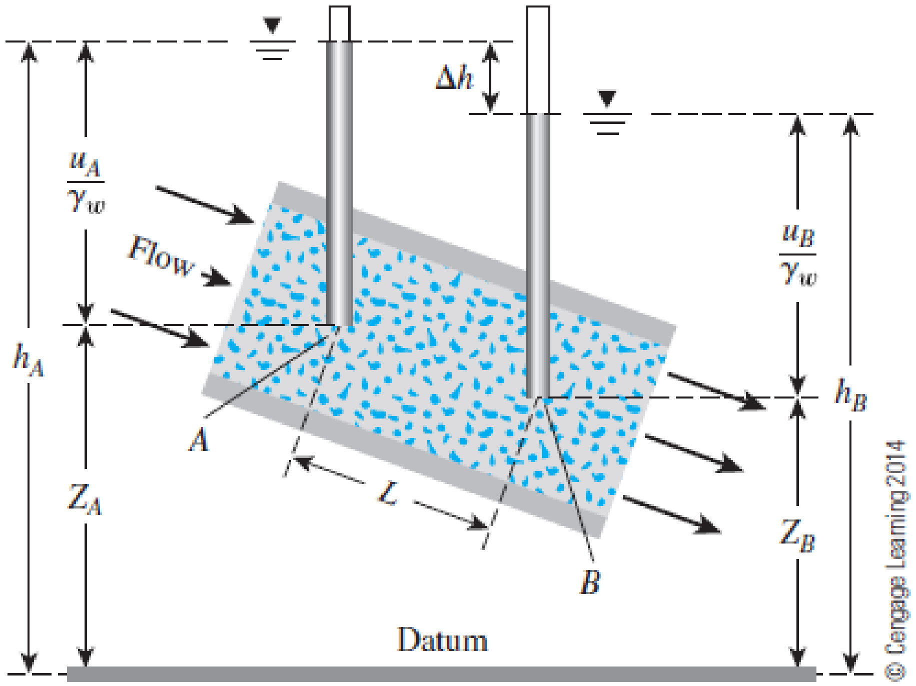


Figure 7.1 Pressure, elevation, and total heads for flow of water through soil

Air mengalir dari energi yang tinggi menuju energi yang rendah. Berdasarkan rumus Bernoulli, Total head adalah penjumlahan dari pressure head, velocity head, dan elevasi head.

Air yang mengalir melalui pori-pori tanah. Untuk menghitung besar perbedaan energi dari suatu titik datum. Kecepatan aliran air sangat kecil sehingga nilai velocity head bisa diababaikan pada perhitungan ini

$$\Delta h = \Delta he + \Delta hp$$

$$\Delta h = selisih\ perbedaan\ energi\ total\ head$$
$$\Delta he = selisih\ perbedaan\ elevasi$$
$$\Delta hp = selisih\ perbedaan\ tekanan$$

$$hp = \frac{u}{\gamma w}$$
$$he = Z$$

$$h = \frac{u}{\gamma_w} + Z$$

Rumus Bernoulli

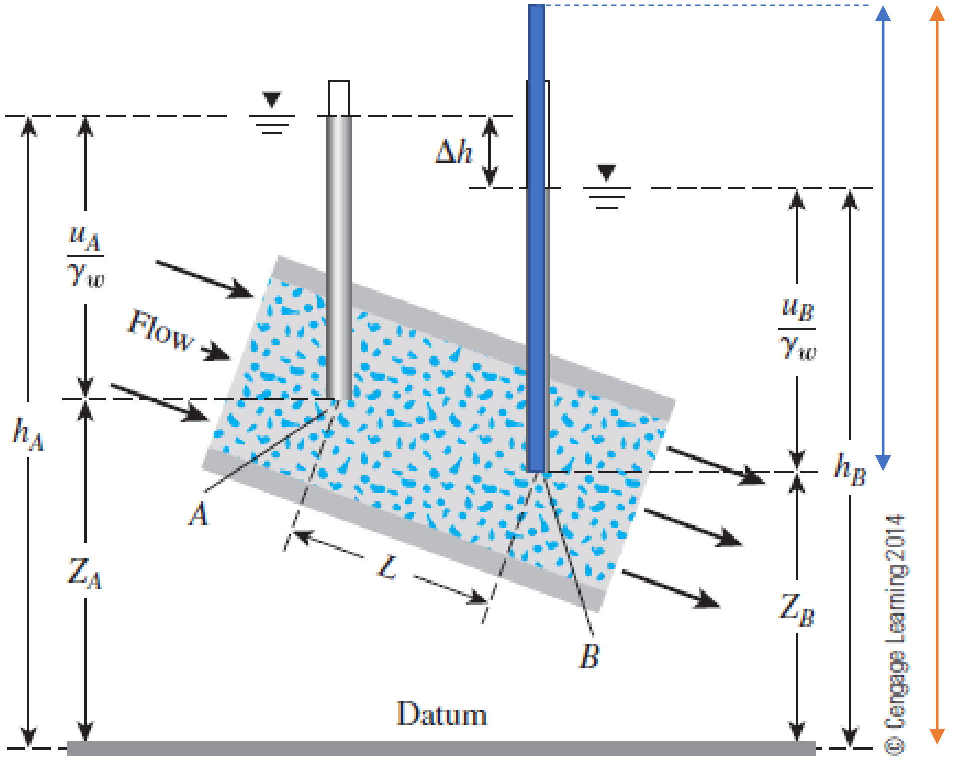


Figure 7.1 Pressure, elevation, and total heads for flow of water through soil

Air mengalir dari energi yang tinggi menuju energi yang rendah. Berdasarkan rumus Bernoulli, Total head adalah penjumlahan dari pressure head, velocity head, dan elevasi head.

Air yang mengalir melalui pori-pori tanah. Untuk menghitung besar perbedaan energi dari suatu titik datum. Kecepatan aliran air sangat kecil sehingga nilai velocity head bisa diababaikan pada perhitungan ini

$$\Delta h = \Delta he + \Delta hp$$

$$\Delta h = selisih\ perbedaan\ energi\ total\ head$$
$$\Delta he = selisih\ perbedaan\ elevasi$$
$$\Delta hp = selisih\ perbedaan\ tekanan$$

$$hp = \frac{u}{\gamma w}$$
$$he = Z$$

$$h = \frac{u}{\gamma_w} + Z$$

Rumus Bernoulli

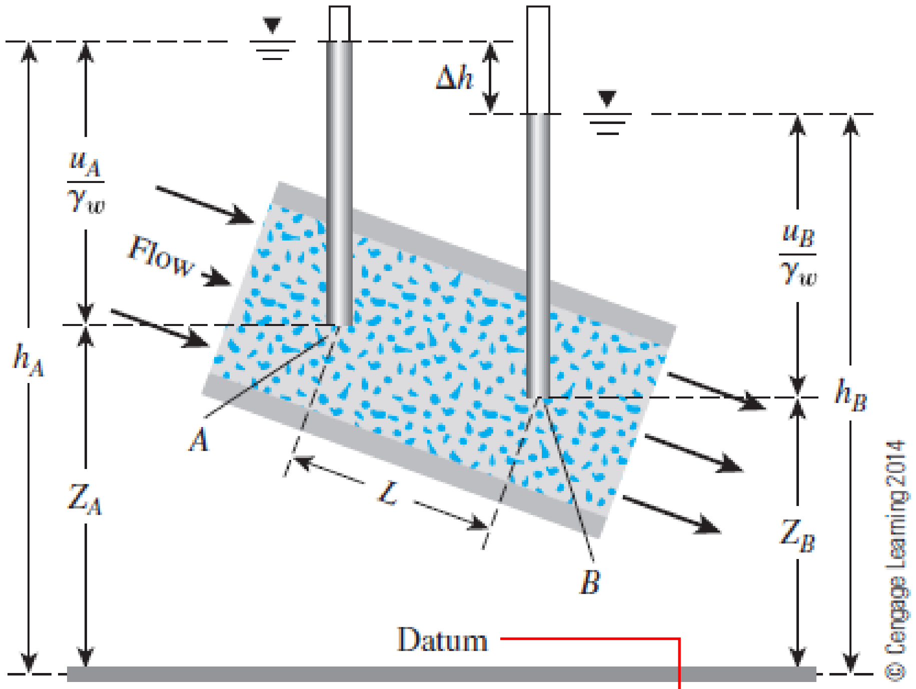


Figure 7.1 Pressure, elevation, and total heads for flow of water through soil

Lokasi Datum diasumsikan

$$\Delta h = hA - hB$$

$$hA = hpA + heA$$

$$hB = hpB + heB$$

$$hA = \frac{uA}{\gamma w} + Z_A$$

$$hB = \frac{uB}{\gamma w} + Z_B$$

$$h = \frac{u}{\gamma_w} + Z$$

$$hp = \frac{u}{\gamma w}$$

$$he = Z$$

Contoh

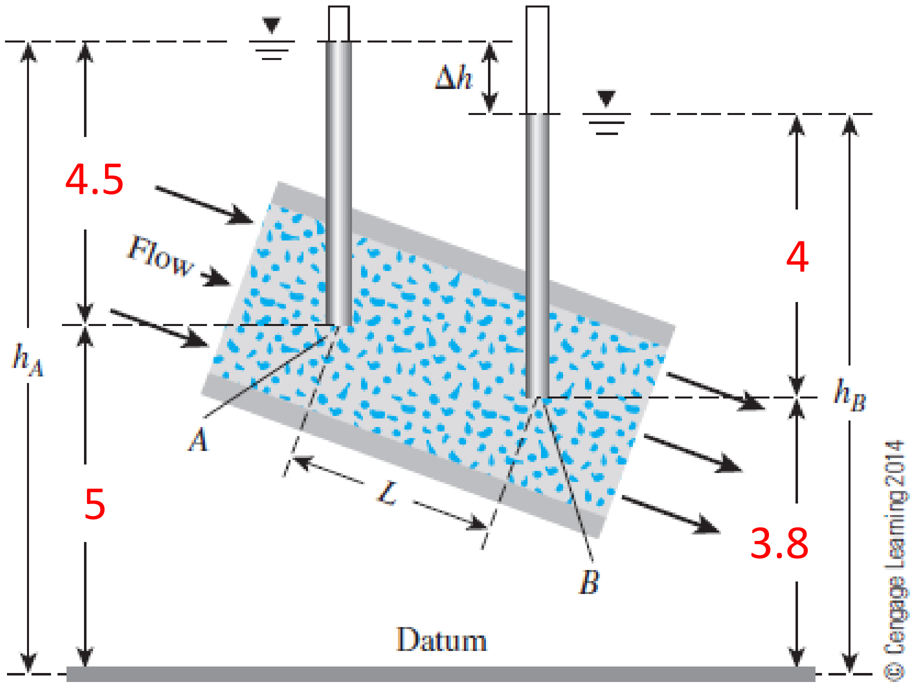


Figure 7.1 Pressure, elevation, and total heads for flow of water through soil

Perbedaan total Head dari titik A ke titik B

$$\Delta h = hA - hB$$

$$hA = hpA + heA$$
$$hA = 4.5 + 5 = 9.5$$
$$hB = hpB + heB$$
$$hB = 4 + 3.8 = 7.8$$

$$\Delta h = 9.5 - 7.8 = 1.7m$$

Terdapat perbedaan tinggi total head sebesar 1.7 m. air mengalir dari titik A menuju titik B

Contoh

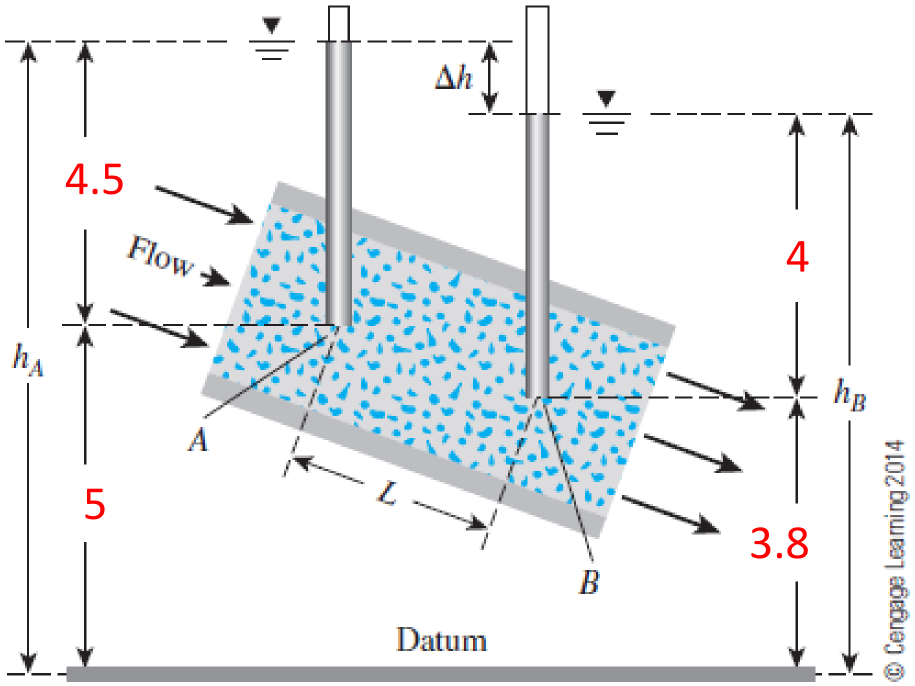


Figure 7.1 Pressure, elevation, and total heads for flow of water through soil

Perbedaan total Head dari titik A ke titik B

Δh dapat disebut juga kehilangan energi. Dapat dihitung dengan rumus berikut :

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

$i = gradien\ hidraulik$

L= jarak antara titik A ke B, atau Panjang aliran dimana kehilangan energi terjadi

Hukum Darcy

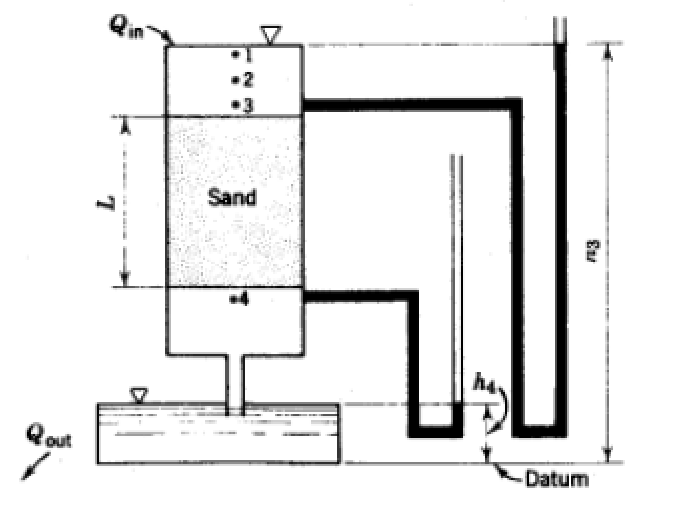
$$v = ki \tag{7.6}$$

where v = *discharge velocity*, which is the quanity of water flowing in unit time through a unit gross cross-sectional area of soil at right angles to the direction of flow
k = hydraulic conductivity (otherwise known as the coefficient of permeability)

$$q = vA = A_v v_s$$

where v_s = seepage velocity
A_v = area of void in the cross section of the specimen

Hukum Darcy



- Persamaan Darcy:

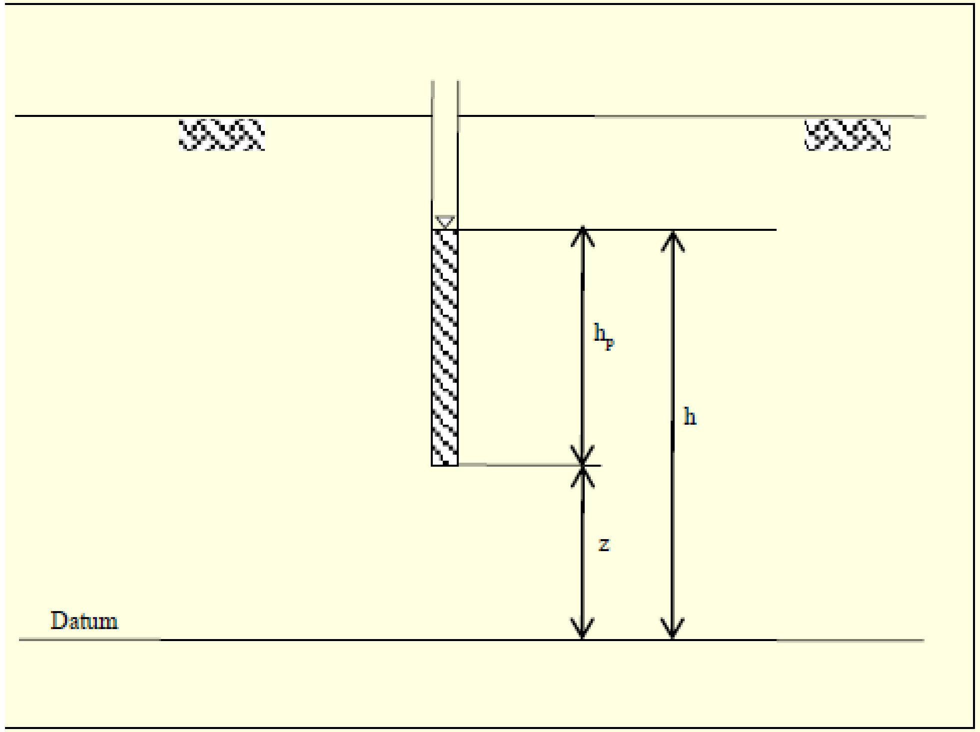
$$Q = k\frac{h_3 - h_4}{L}A = k\,i\,A \qquad Q = v\,A \;\; \text{dengan} \;\; v = k\frac{h_3 - h_4}{L} = k\,i$$

- Dimana:

v = kecepatan pengaliran,

i = hydraulic gradient

Hukum Darcy



$h = h_p + h_e + h_v = \text{constant}$

di mana:

- h = *total head*,
- h_p = $\dfrac{u}{\gamma_w}$ = *pressure head*,
- h_e = z = *elevation head*,
- h_v = $\dfrac{v^2}{2g}$ = *velocity head*,
- u = tekanan air pori,
- z = elevasi dari suatu titik terhadap suatu datum,
- v = kecepatan pengaliran, dan
- g = percepatan gravitasi.

Uji Permeabilitas di laboratorium

Constant Head Test

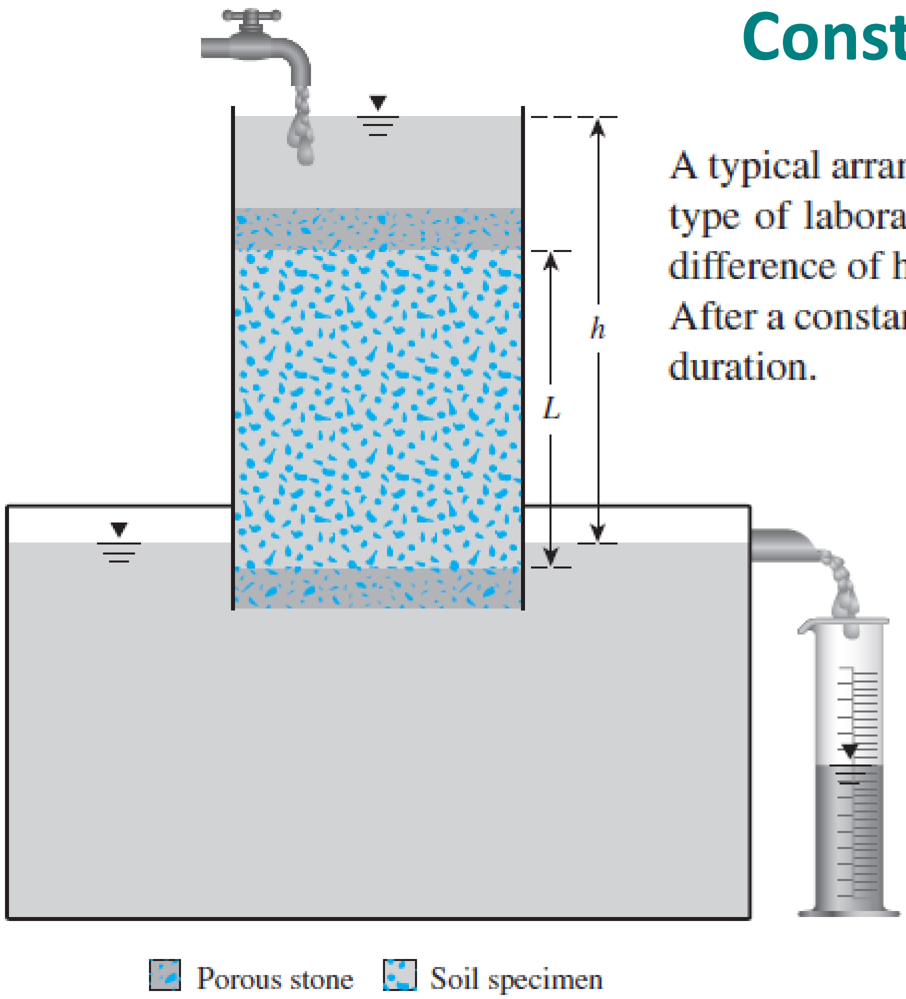


Figure 7.5 Constant-head permeability test

A typical arrangement of the constant-head permeability test is shown in Figure 7.5. In this type of laboratory setup, the water supply at the inlet is adjusted in such a way that the difference of head between the inlet and the outlet remains constant during the test period. After a constant flow rate is established, water is collected in a graduated flask for a known duration.

The total volume of water collected may be expressed as

$$Q = Avt = A(ki)t$$

where Q = volume of water collected
A = area of cross section of the soil specimen
t = duration of water collection

$$i = \frac{h}{L}$$ where L = length of the specimen,

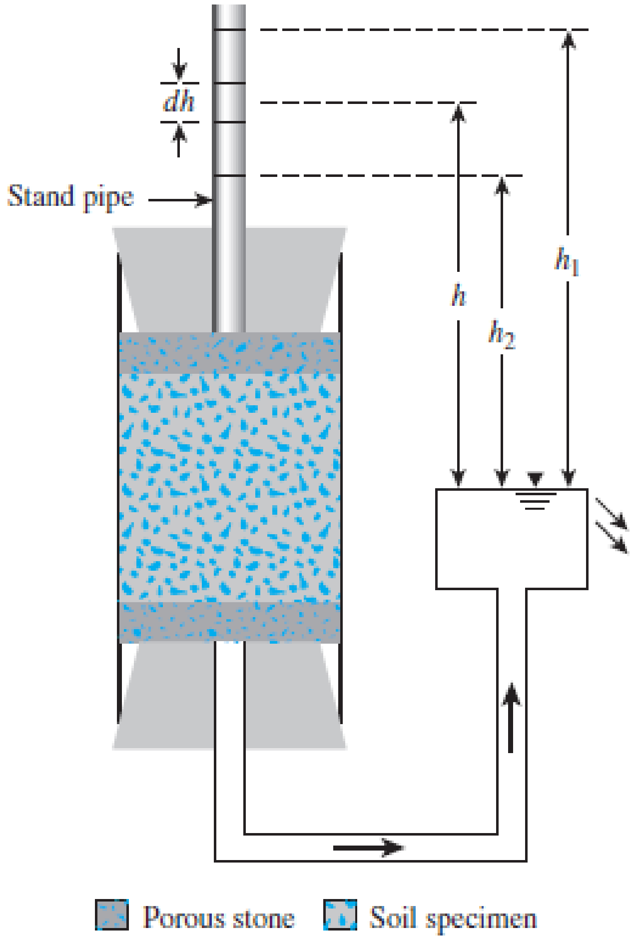
$$Q = A\left(k\frac{h}{L}\right)t$$

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

a constant-head test arrangement in the laboratory for a test on a granular soil.

Uji Permeabilitas di laboratorium

Falling - Head Test



A typical arrangement of the falling-head permeability test is shown in Figure. Water from a standpipe flows through the soil. The initial head difference h_1 at time t=0 is recorded, and water is allowed to flow through the soil specimen such that the final head difference at time $t = t_2$ is h_2.

$$q = k\frac{h}{L}A$$

where q = flow rate
a = cross-sectional area of the standpipe
A = cross-sectional area of the soil specimen

$$k = 2.303\frac{aL}{At}\log_{10}\frac{h_1}{h_2}$$

Contoh

Constant Head Test

- $L = 30$ cm
- A = area of the specimen = 177 cm^2
- Constant-head difference, $h = 50$ cm
- Water collected in a period of 5 min = 350 cm^3

Calculate the hydraulic conductivity in cm/sec.

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

Given $Q = 350$ cm^3, $L = 30$ cm, $A = 177$ cm^2, $h = 50$ cm, and $t = 5$ min, we have

$$k = \frac{(350)(30)}{(177)(50)(5)(60)} = \mathbf{3.95 \times 10^{-3}\ cm/sec}$$

Falling - Head Test

For a falling-head permeability test, the following values are given:

- Length of specimen = 200 mm.
- Area of soil specimen = 1000 mm^2.
- Area of standpipe = 40 mm^2.
- Head difference at time $t = 0$ = 500 mm.
- Head difference at time $t = 180$ sec = 300 mm.

Determine the hydraulic conductivity of the soil in cm/sec.

$$k = 2.303 \frac{aL}{At} \log_{10}\left(\frac{h_1}{h_2}\right)$$

We are given $a = 40$ mm^2, $L = 200$ mm, $A = 1000$ mm^2, $t = 180$ sec, $h_1 = 500$ mm, and $h_2 = 300$ mm,

$$k = 2.303 \frac{(40)(200)}{(1000)(180)} \log_{10}\left(\frac{500}{300}\right)$$
$$= \mathbf{2.27 \times 10^{-2}\ cm/sec}$$

note

Nilai **k** sering disebut sebagai koefisien permeabilitas atau konduktivitas hidraulik
k dibuat dalam satuan panjang per waktu

Rentang nilai koefisien permabilitas (k) berdasarkan tipe tanah

Soil type	*k* cm/sec
Clean gravel	100–1.0
Coarse sand	1.0–0.01
Fine sand	0.01–0.001
Silty clay	0.001–0.00001
Clay	<0.000001

note

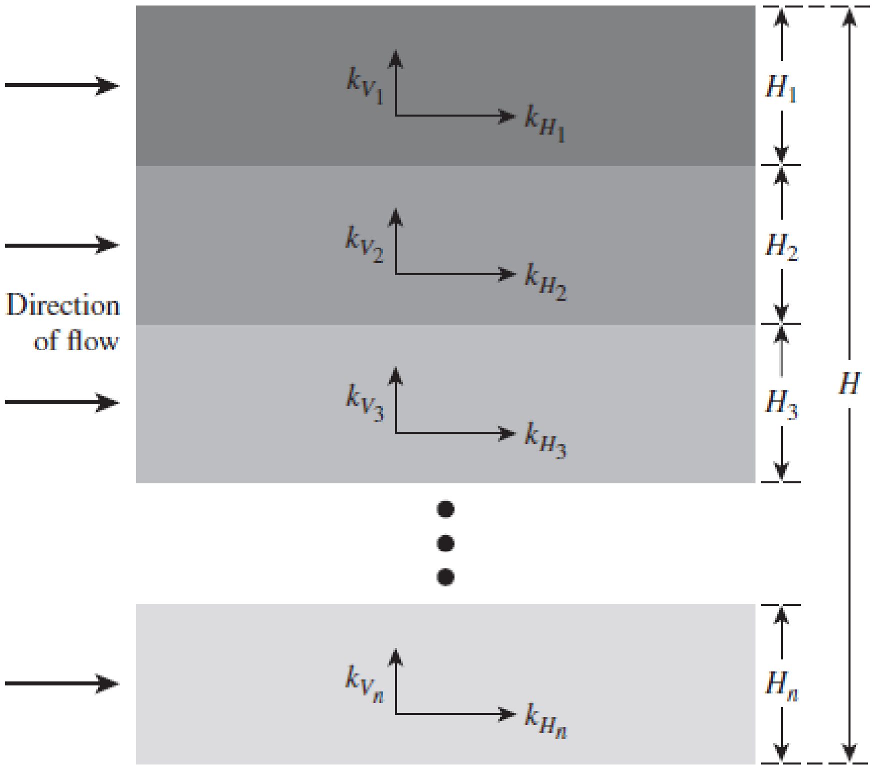
Rasio nilai koefisien permebilitas arah horizontal dan vertikal

Soil type	k_H/k_V	Reference
Organic silt with peat	1.2 to 1.7	Tsien (1955)
Plastic marine clay	1.2	Lumb and Holt (1968)
Soft clay	1.5	Basett and Brodie (1961)
Varved clay	1.5 to 1.7	Chan and Kenney (1973)
Varved clay	1.5	Kenney and Chan (1973)
Varved clay	3 to 15	Wu et al. (1978)
Varved clay	4 to 40	Casagrande and Poulos (1969)

Most soils are not isotropic with respect to permeability. In a given soil deposit, the magnitude of k changes with respect to the direction of flow. Figure 7.19 shows a soil layer through which water flows in a direction inclined at an angle α with the vertical. Let the hydraulic conductivity in the vertical ($\alpha = 0$) and horizontal ($\alpha = 90°$) directions be k_V and k_H, respectively. The magnitudes of k_V and k_H in a given soil depend on several factors, including the method of deposition in the field.

note

In a stratified soil deposit where the hydraulic conductivity for flow in a given direction changes from layer to layer, an equivalent hydraulic conductivity can be computed to simplify calculations. The following derivations relate to the equivalent hydraulic conductivities for flow in vertical and horizontal directions through multilayered soils with horizontal stratification.



$$k_{H(\text{eq})} = \frac{1}{H}\left(k_{H_1}H_1 + k_{H_2}H_2 + k_{H_3}H_3 + \ldots + k_{H_n}H_n\right)$$

$$k_{v(\text{eq})} = \frac{H}{\left(\frac{H_1}{k_{V_1}}\right) + \left(\frac{H_2}{k_{V_2}}\right) + \left(\frac{H_3}{k_{V_3}}\right) + \cdots + \left(\frac{H_n}{k_{V_n}}\right)}$$

Seepage

Soil Mechanic I

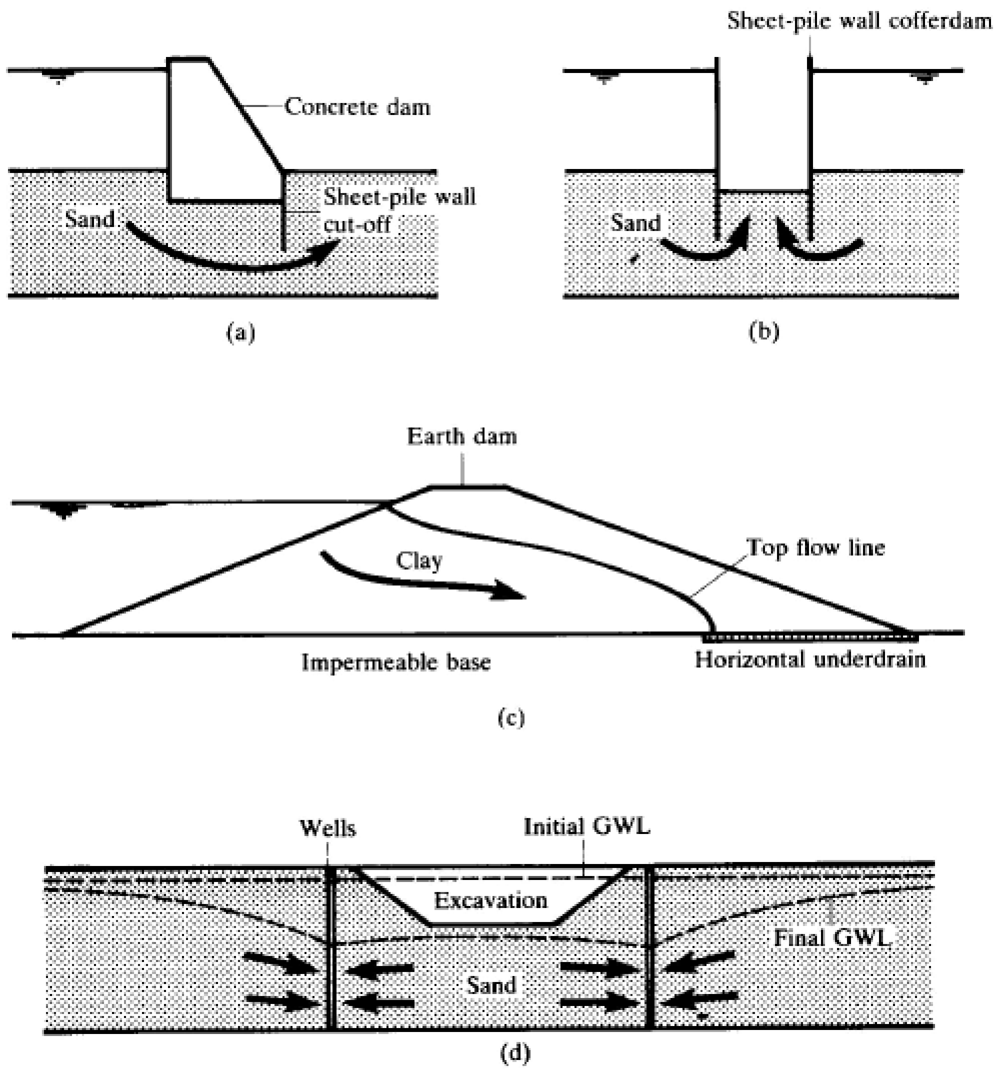
Sherly Meiwa , ST., MT

Department of Civil Engineering
Universitas Komputer Indonesia
Bandung, 2020

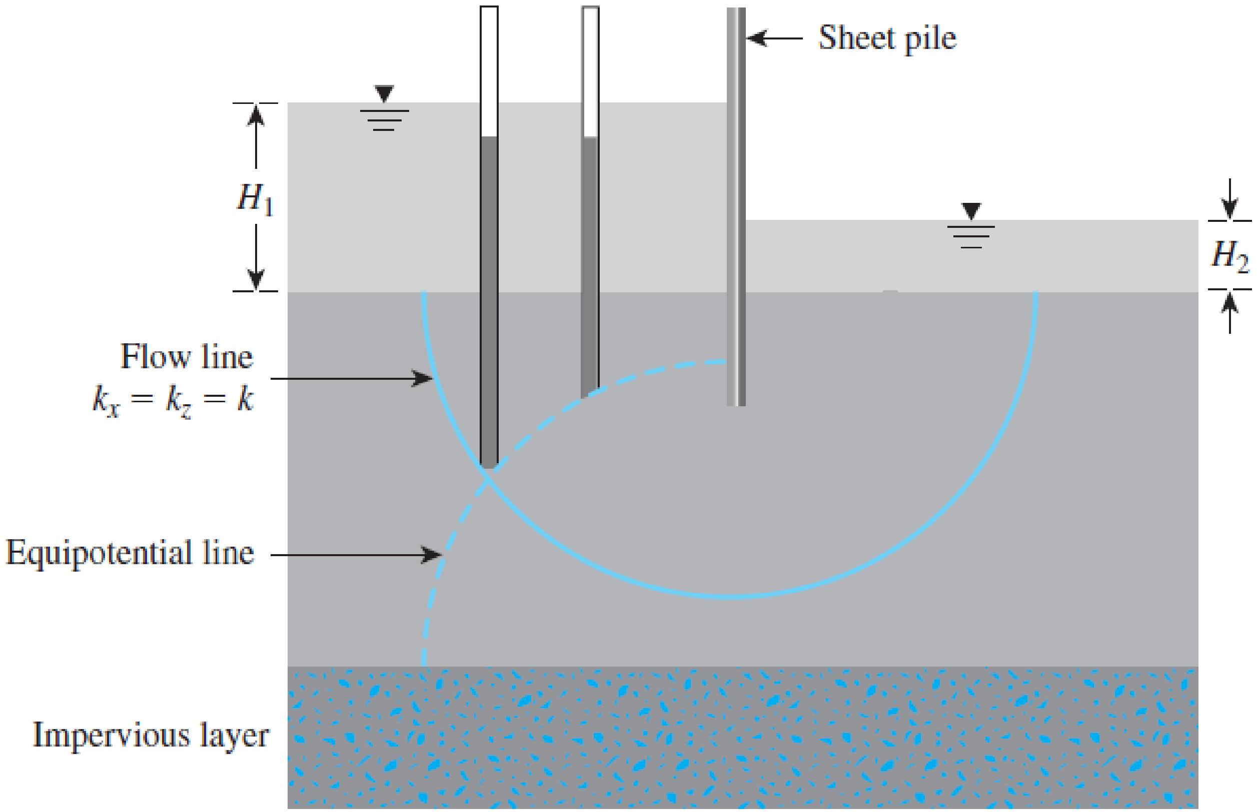
Tujuan Pembelajaran

Dapat menghitung besarnya rembesan dalam tanah dan menetukan tekanan uplift yang terjadi pada bangunan air.

Seepage (Rembesan) : untuk mengetahui jumlah rembesan air yang mengalir pada tanah, baik dibawah dinding penahan (sheet pile) atau pun yang melewati pada tubuh bendungan.



Flownet



Flow line : Garis aliran rembesan

Equipotential line : garis dengan potential head yang sama

Flownet

Sekumpulan *flow lines & equipotential line,* menurut Darcy :

$$\Delta q = A\,.\,v = A\,.\,k\,.\,i = (a\,.\,1\,)\,k\,.\frac{\Delta h}{b}$$

$$\Delta q = \frac{a}{b}\,.\,k\,.\Delta h$$

$$diasumsikan\ a{=}b$$

$$\Delta h = \frac{h1-h2}{Nd} = \frac{\Delta H}{Nd}$$

$$\Delta H = h1 - h2$$

Dimana : Nd = Equipotential drop

$$Sehingga\ Debit\ per\ satuan\ panjang\ adalah$$

$$\Delta q = \frac{a}{b}\,.\,k\,.\frac{h1-h2}{Nd}$$

$$\Delta q = k\,.\frac{\Delta H}{Nd}$$

Flownet

Debit Total

Dimana : Nd = Equipotential drop

Total Flow-nya menjadi :

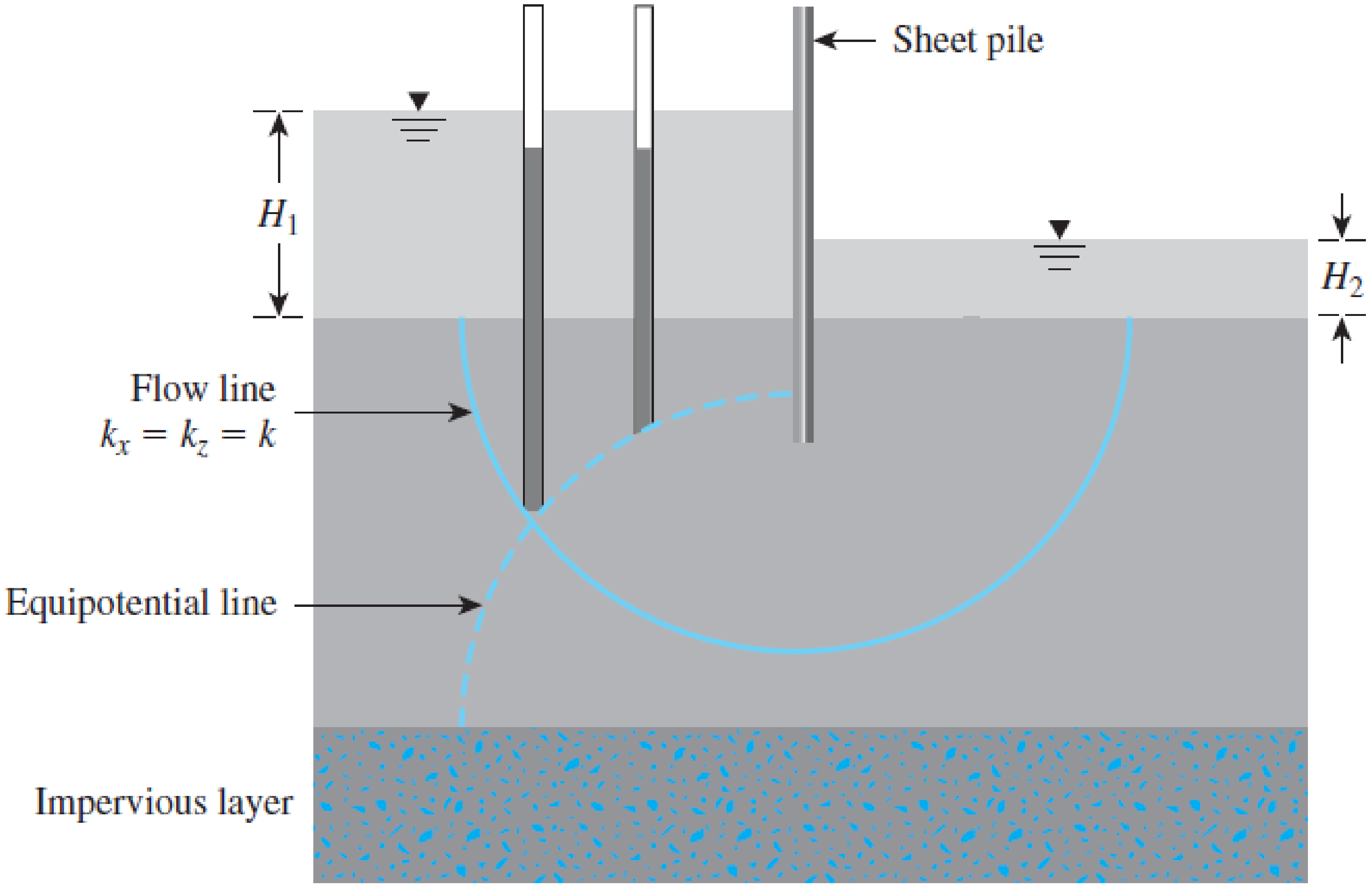
$$q = \Sigma\, \Delta q \;= Nf \,.\, k \,.\, \left[\frac{a}{b}\right] \left[\frac{h1 - h2}{Nd}\right]$$

$$q = k \left[\frac{Nf}{Nd}\right] \Delta H \left[\frac{a}{b}\right]$$

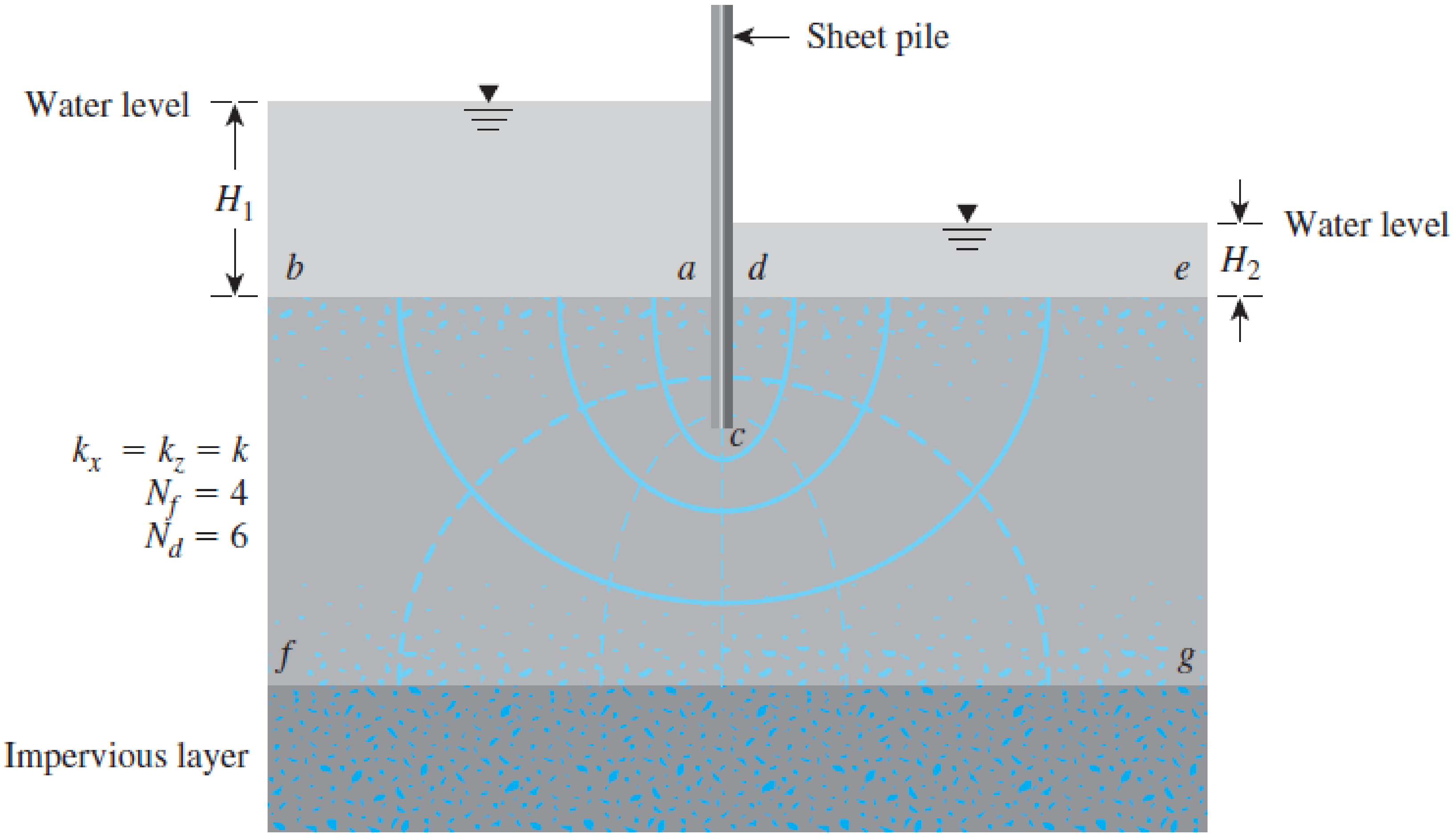
Untuk a = b persamaan menjadi :

Atau : $q_{total} = k \left[\frac{Nf}{Nd}\right] \Delta H$ $\quad\quad \Delta H = h1 - h2$

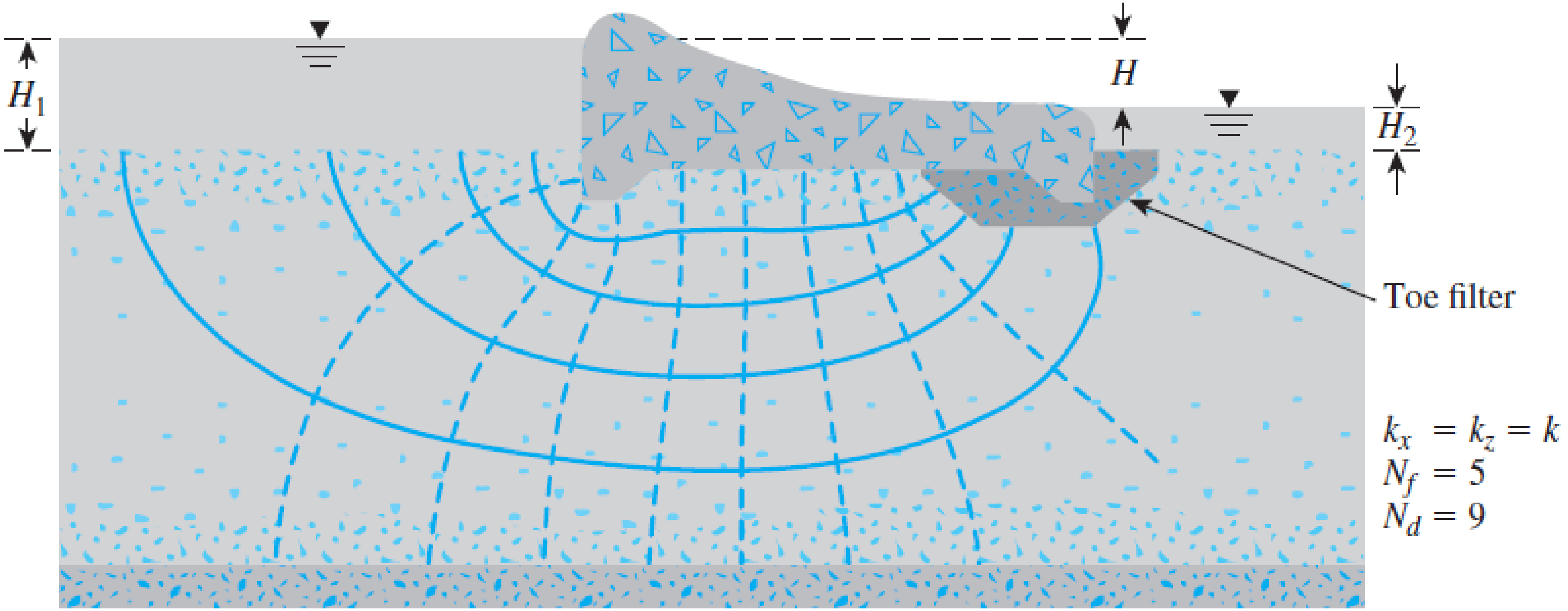
Flownet (Contoh)



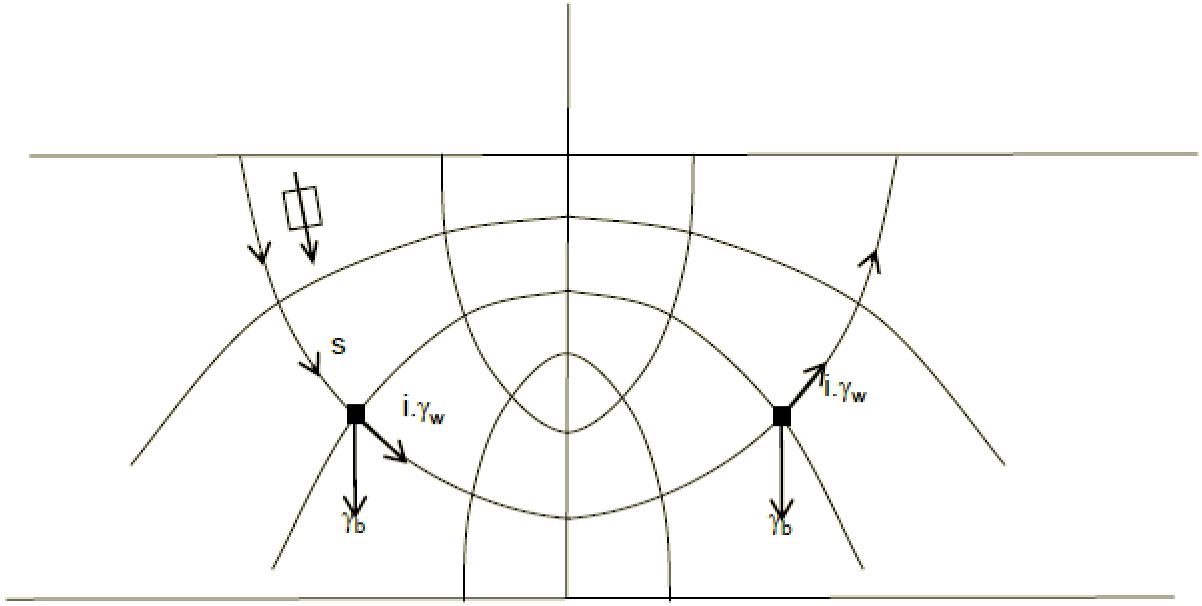
Flownet (Contoh)

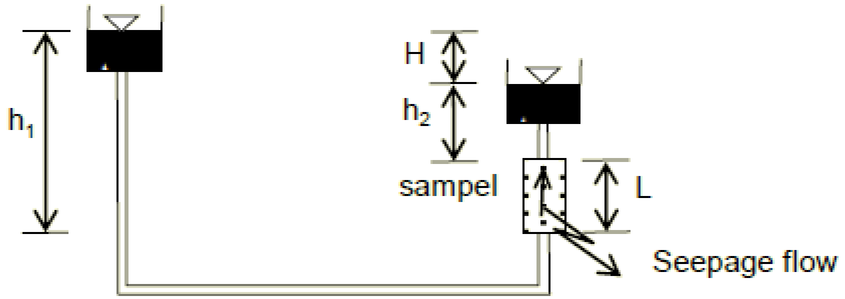


Flownet (Contoh)



Seepage Force





Seepage Force

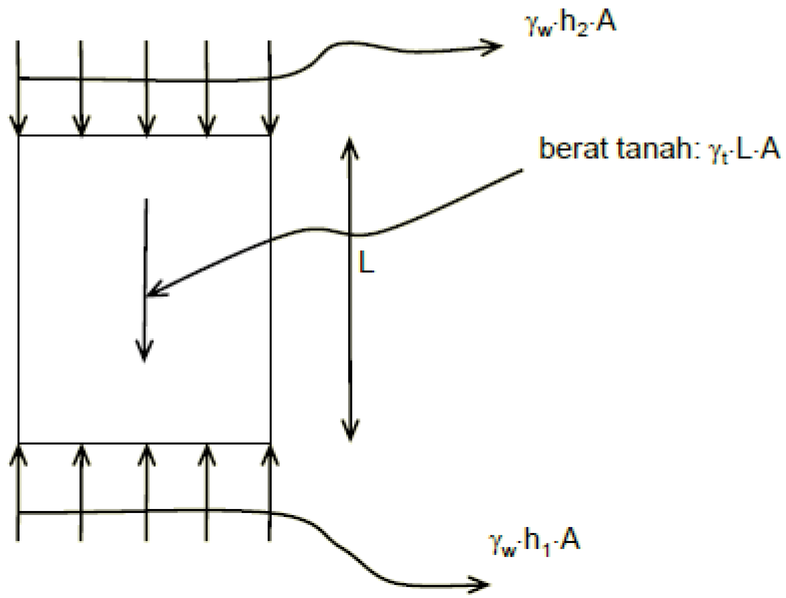
Resultante Force $= \gamma_t LA - \gamma_w (h_1 - h_2) A$

$$Body\ force = \frac{force}{volume}$$

$$= \frac{\gamma_t LA - \gamma_w (h_1 - h_2) A}{LA}$$

$$= \gamma_t - \gamma_w \left(\frac{H + L}{L} \right) = \gamma_t - \gamma_w (1 + i)$$

$$= \gamma_{bouyant} - i\gamma_w$$



I critis $= \frac{\gamma'}{\gamma w}$

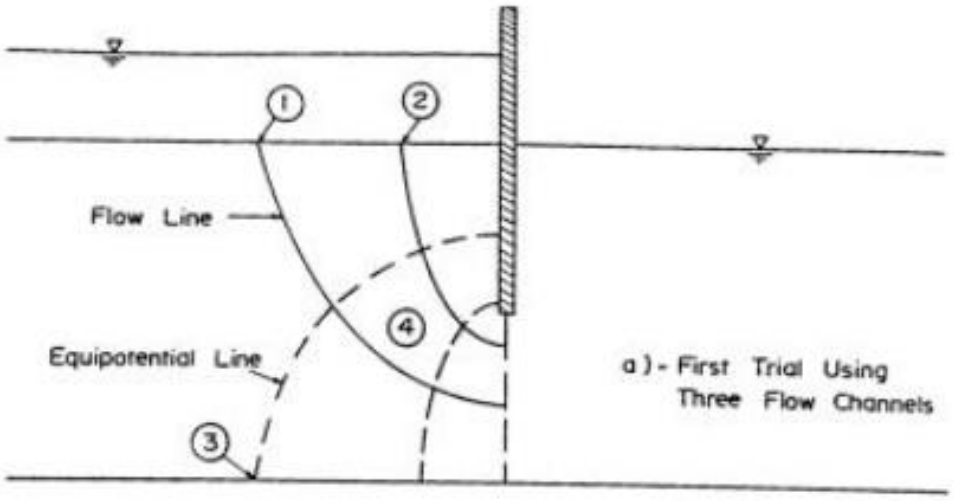
Sand Boiling

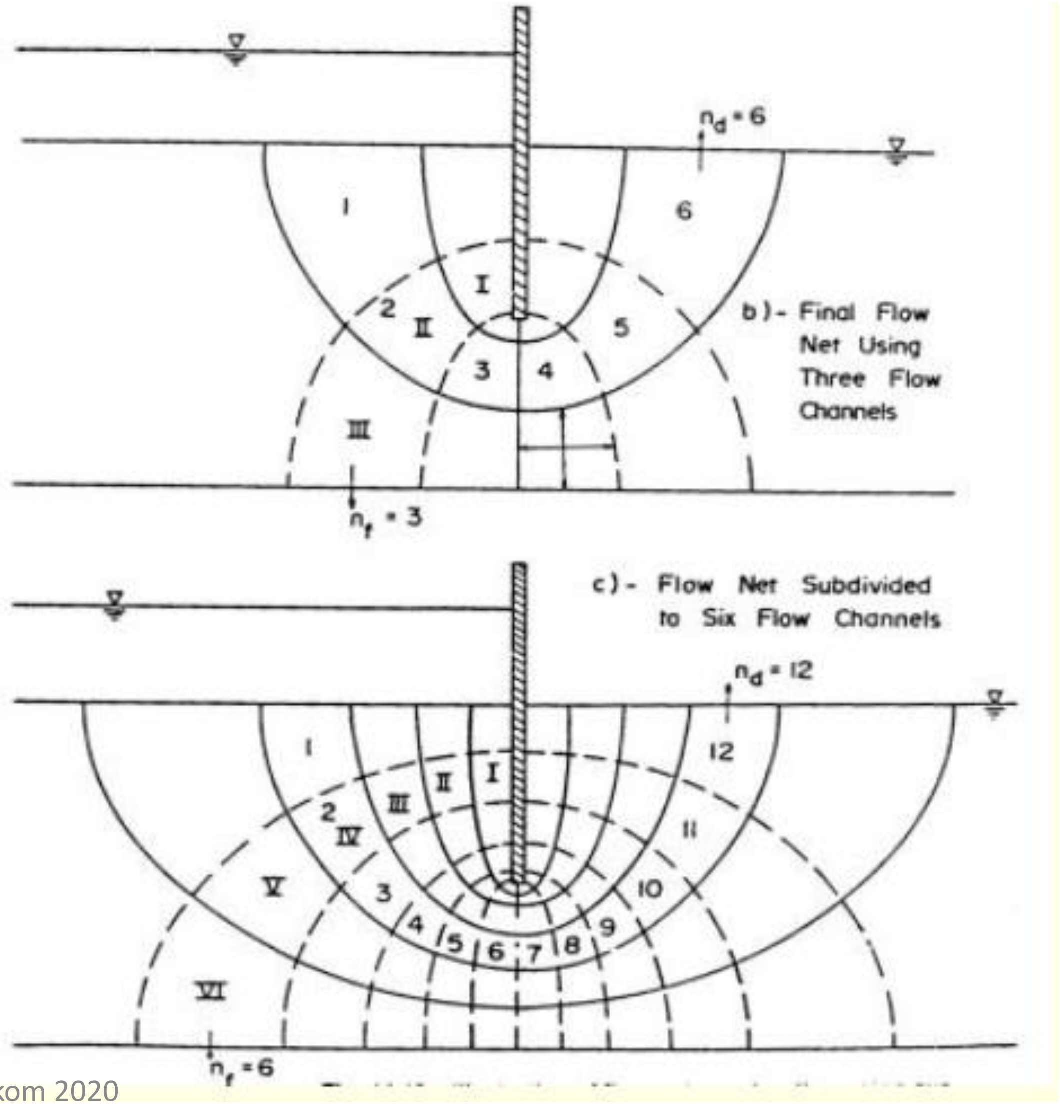
Boiling adalah aliran air (dan tanah halus) ke dasar lubang galian akibat tekqanan air di luar galian yang lebih besar tekanan di dalam galian

Sand Boiling

Apabila rembesan di bawah banguan air tidak dikontrol secara sempurna, maka keadaan tersebut mengasilkan gradien hidrolik yang cukup besar di tempat keluar (bagian hilir sungai) dekat konstruksi. Gradien yang tinggi di tempat keluar tersebut berarti gaya rembes juga besar. Sehingga menyebabkan tanah menggelembung ke atas (heave) atau menyebabkan tanah kehialang kekuatannya. Keadaan ini akan mempengaruhi kestabilan bagunan air yang bersangkutan

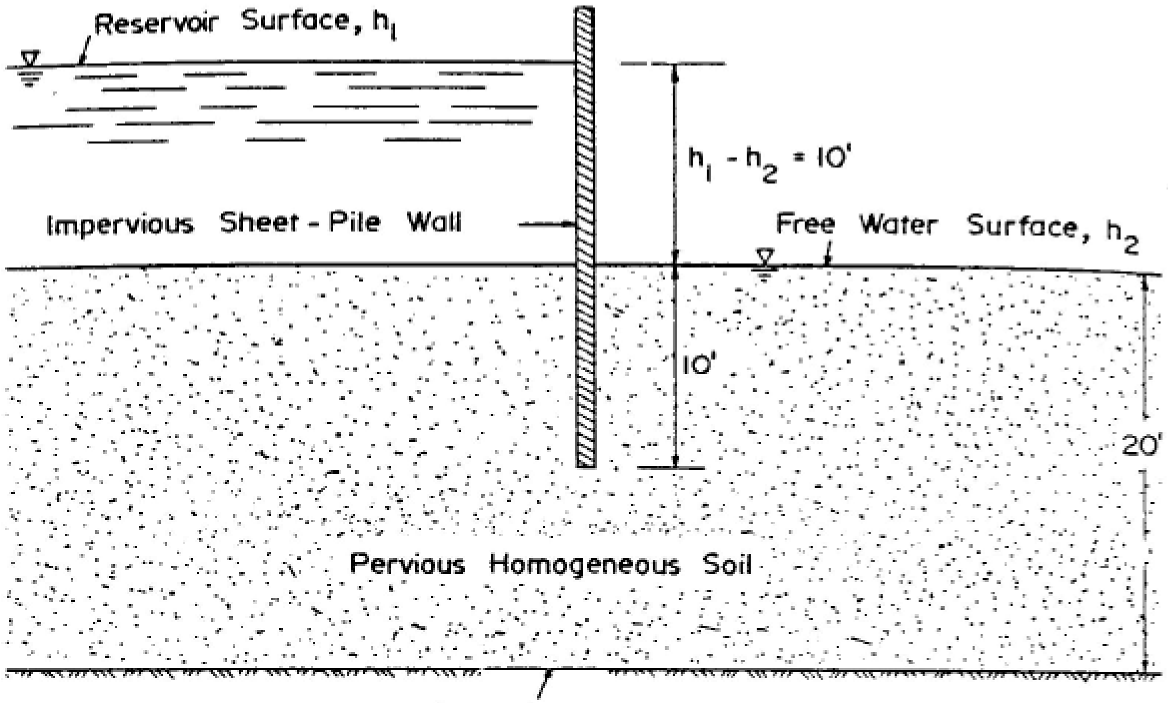
Flownet Construction





$$\text{Transformed section}: \; q = k_e \frac{N_f}{N_d} \Delta H$$

Flownet Construction



a) - Sketch of Problem

Flownet Construction