Vertical Drain

DR. IR. NURLY GOFAR, MSCE

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Preloading + Vertical Drain

Reduces settlement & speeds up primary consolidation

Effective if

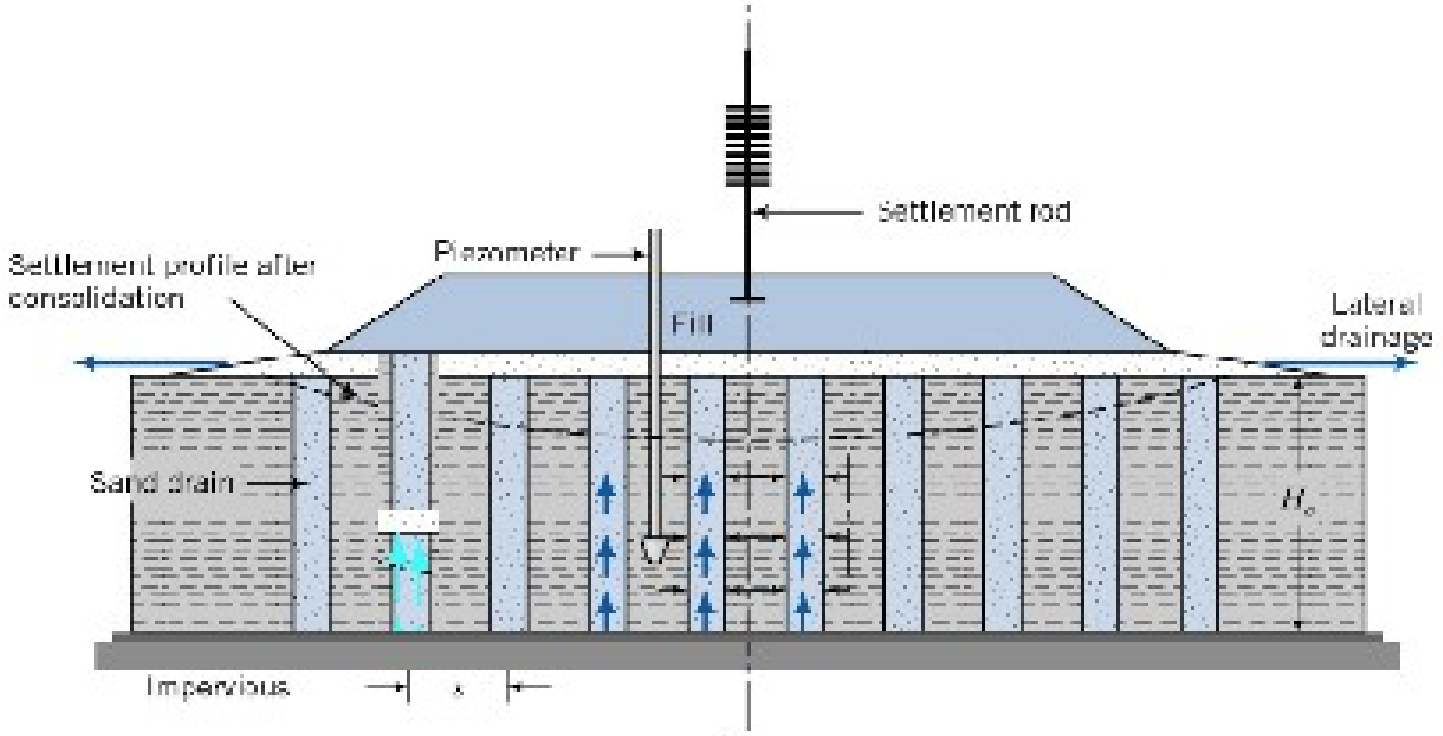
- ***Soft cohesive soils***
- ***Soft clay with horizontal lenses***
- ***No or low organic content***
- **$C_v < 3x\ 10^{-7}\ m^2/sec.$**

Drainage spacing is determined based on the required time and degree of consolidation

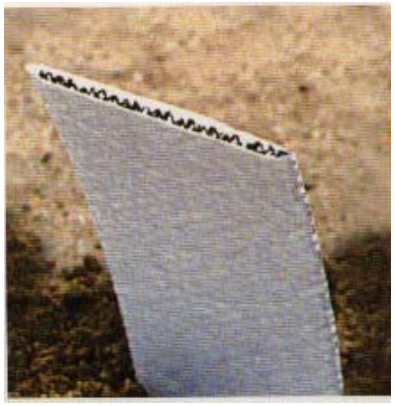
Methods of Providing Vertical Drain

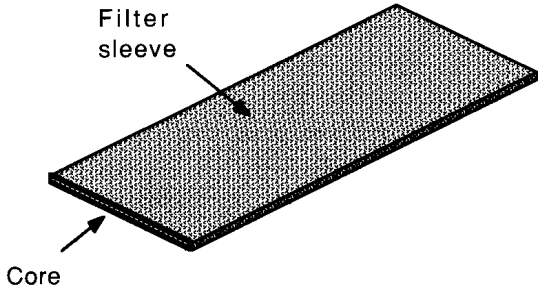
- Sand Drain (typical dia.200-450 mm, spaced 1.5–6 m)
- Sandwick drains (typical dia. 65 mm)
- Geosynthetics drains (strip drains)

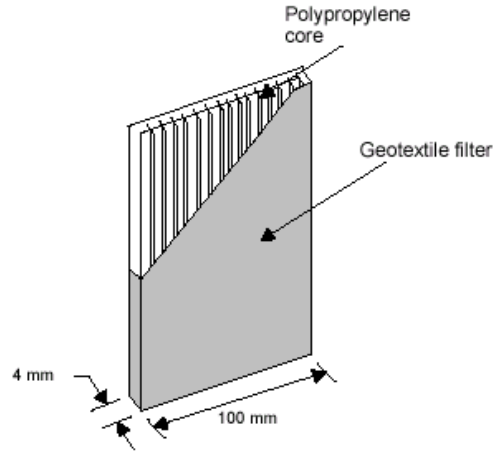
Sand Drain

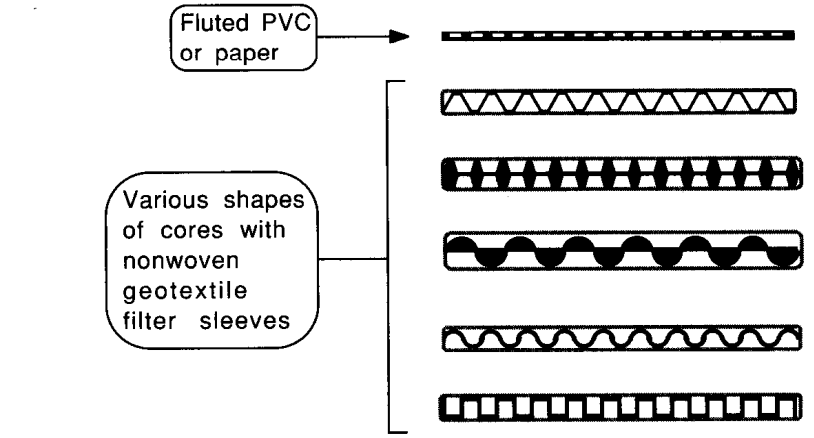

Settlement rod
Piezometer
Settlement profile after consolidation
Fill
Lateral drainage
Sand drain
H_c
Impervious
x

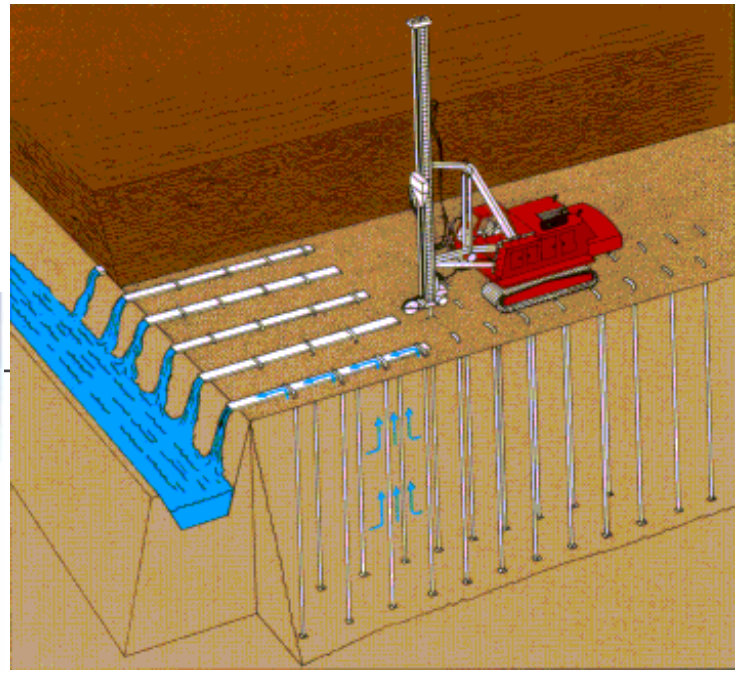
Prefabricated Vertical Drain / Geosynthetics drain (PVD)



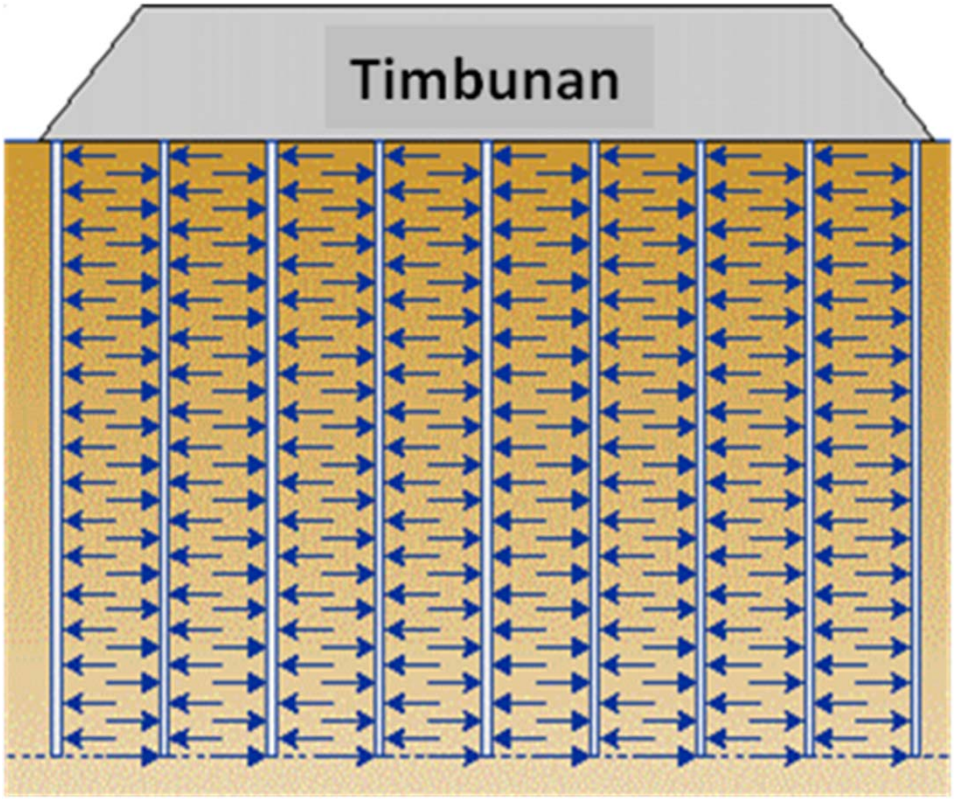


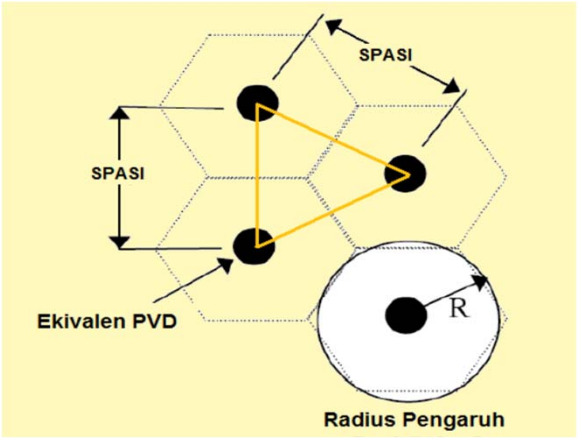


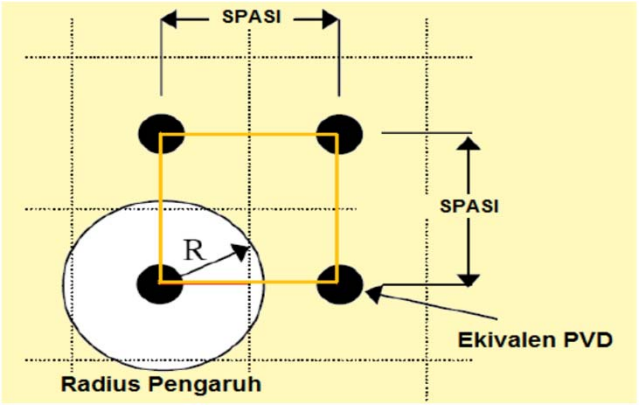




Vertical drains Prinsip Disain







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Aliran air arah radial

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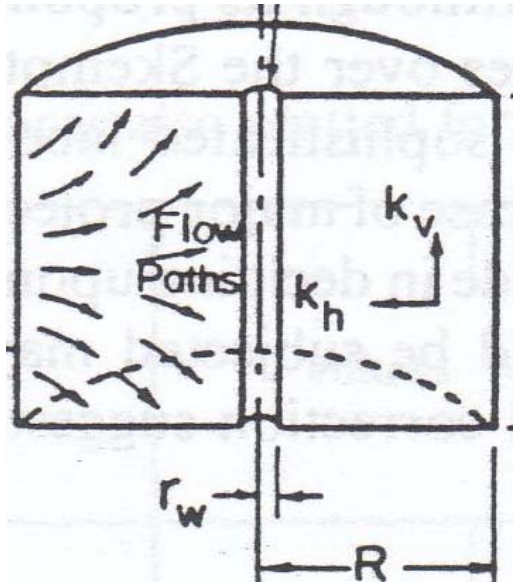
Proses terdisipasinya tekanan ekses air pori pada arah radial diatur melalui persamaan sebagai berikut:

$$\frac{\partial U_e}{\partial t} = C_h \left(\frac{\partial^2 U_e}{\partial r^2} + \frac{1}{r} \frac{\partial U_e}{\partial r} \right)$$

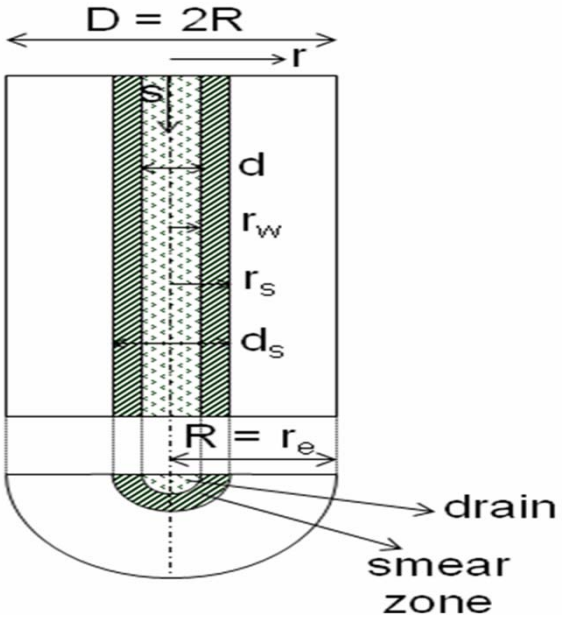


Untuk kasus vertical drain dan dengan asumsi kondisi equal strain, maka solusi dari persamaan di atas adalah:

$$\overline{U_h} = 1 - \exp\left[\frac{-2T_h}{F(n)}\right]$$

dengan

$$T_h = \frac{C_h \cdot t}{r_e^{\,2}} \qquad n = \frac{r_e}{r_w}$$



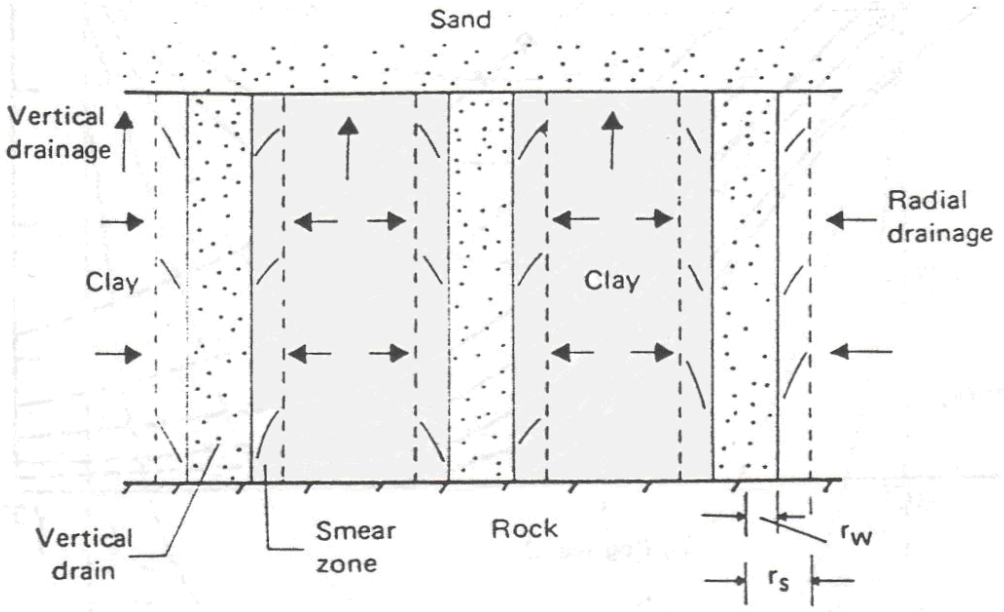
$$F(n) = \frac{n^2}{n^2-1}\ln(n) - \frac{\left(3n^2-1\right)}{4n^2} + \frac{k_r}{r_w k} \cdot \frac{n^2-1}{n^2}$$

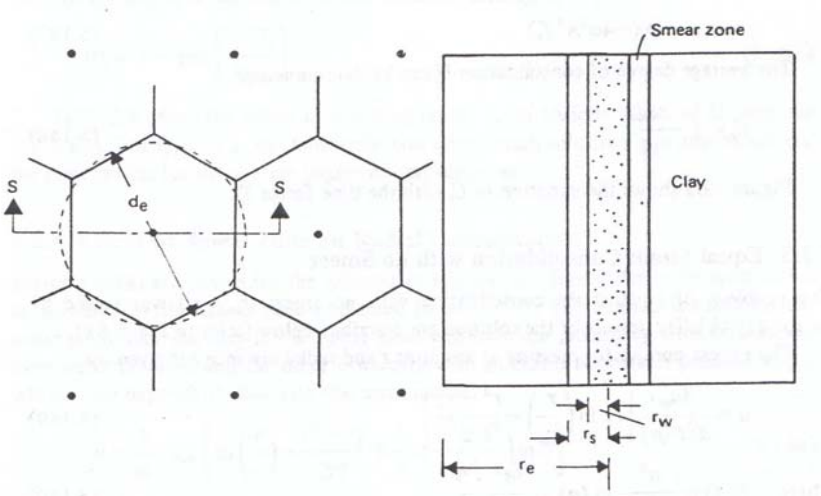
Aliran air arah vertikal dan arah radial

Proses konsolidasi untuk aliran dua arah ini diatur melalui persamaan sebagai berikut:

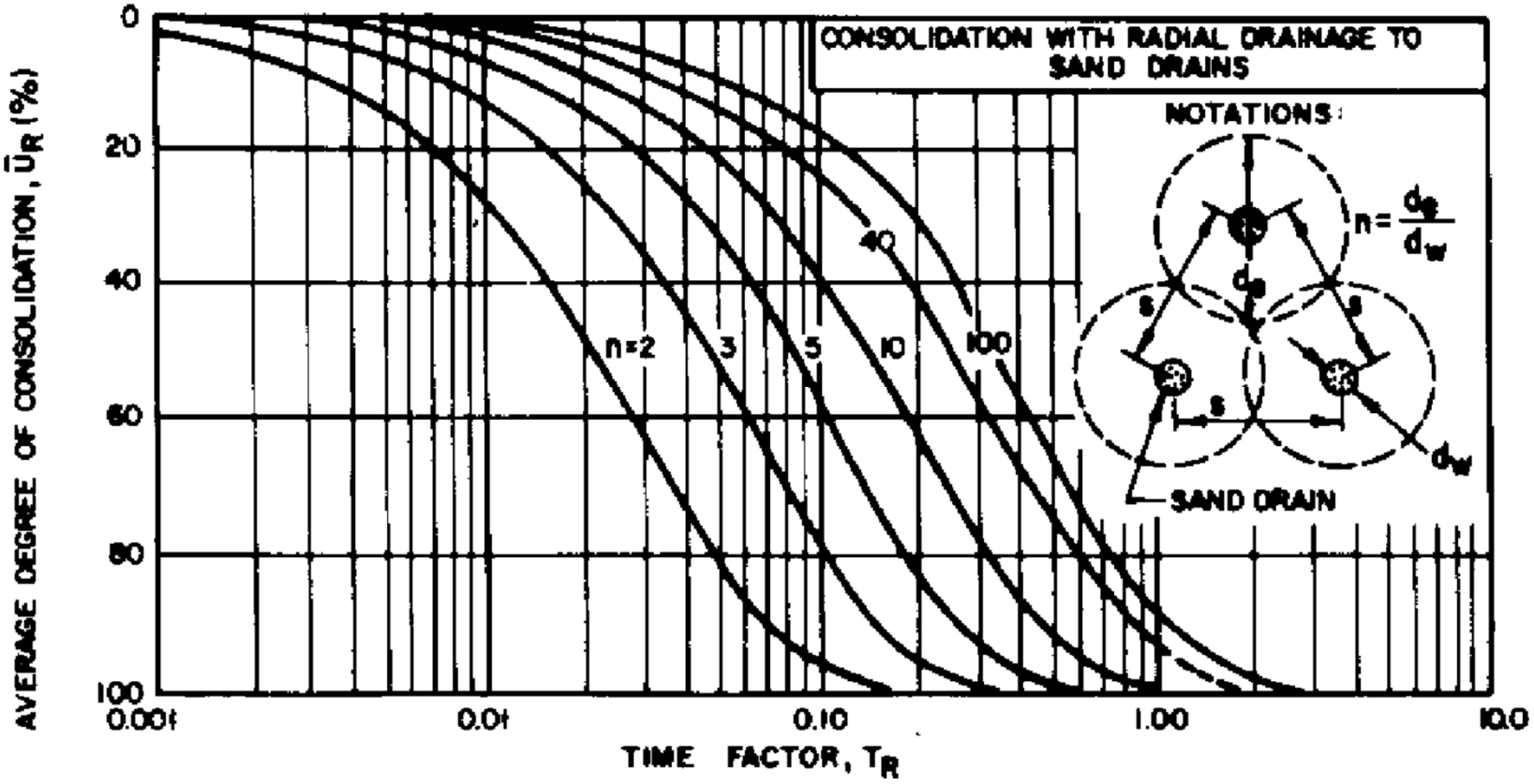
$$\frac{\partial U_e}{\partial t} = C_v \frac{\partial^2 U_e}{\partial z^2} + C_h \left(\frac{\partial^2 U_e}{\partial r^2} + \frac{1}{r} \frac{\partial U_e}{\partial r} \right)$$

$$\overline{U_{vh}} = 1 - \left(1 - \overline{U_v}\right)\left(1 - \overline{U_h}\right)$$

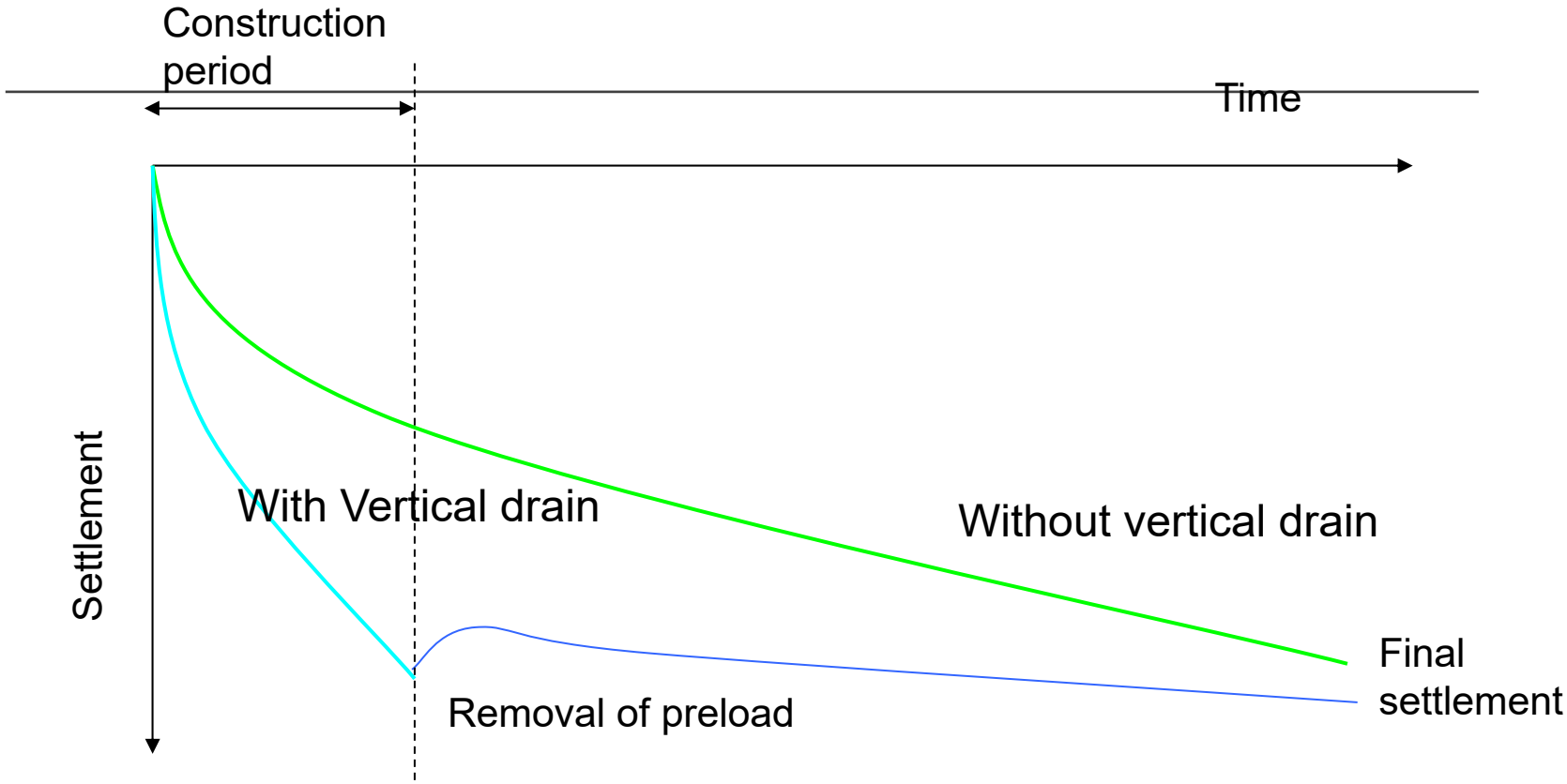




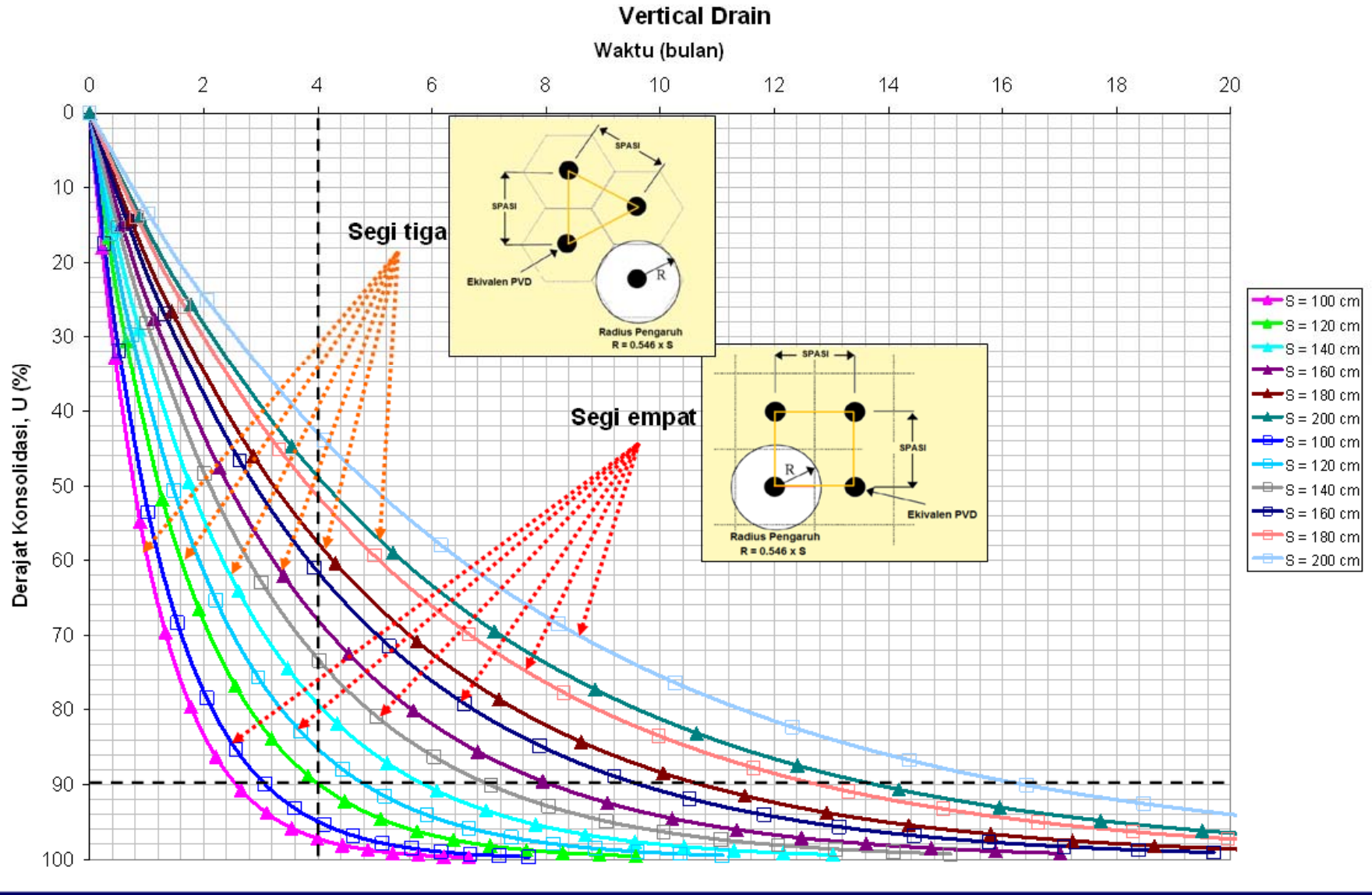
Radial drain (vertical drain)



Effect of Vertical Drain on Final Settlement



Percepatan Proses Konsolidasi dengan PVD



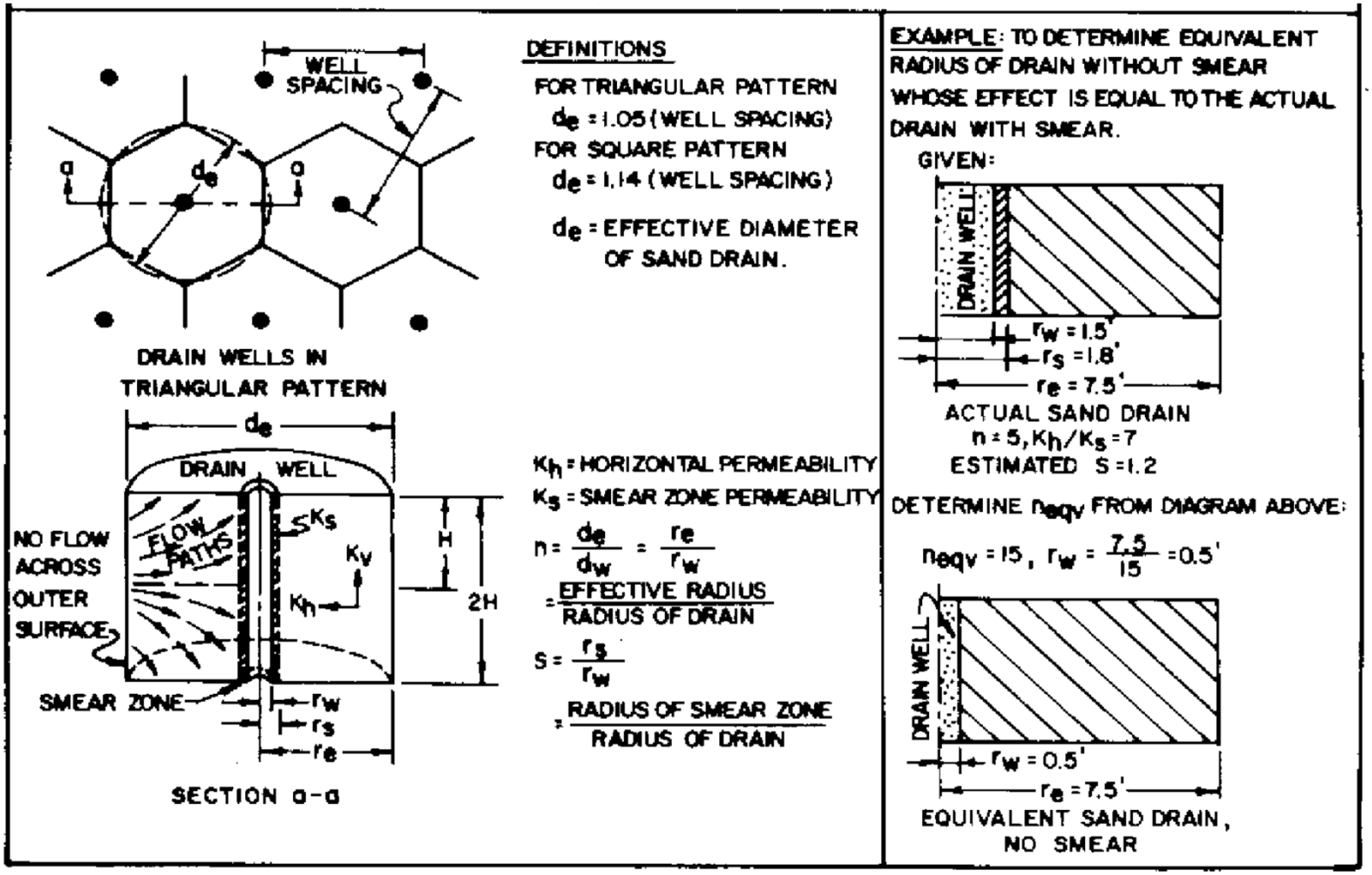
Effect of Smear & Drain Resistance on vertical drain

Smear is the disturbance of the soil adjacent to the drains that can decrease the permeability and slow down the consolidation process

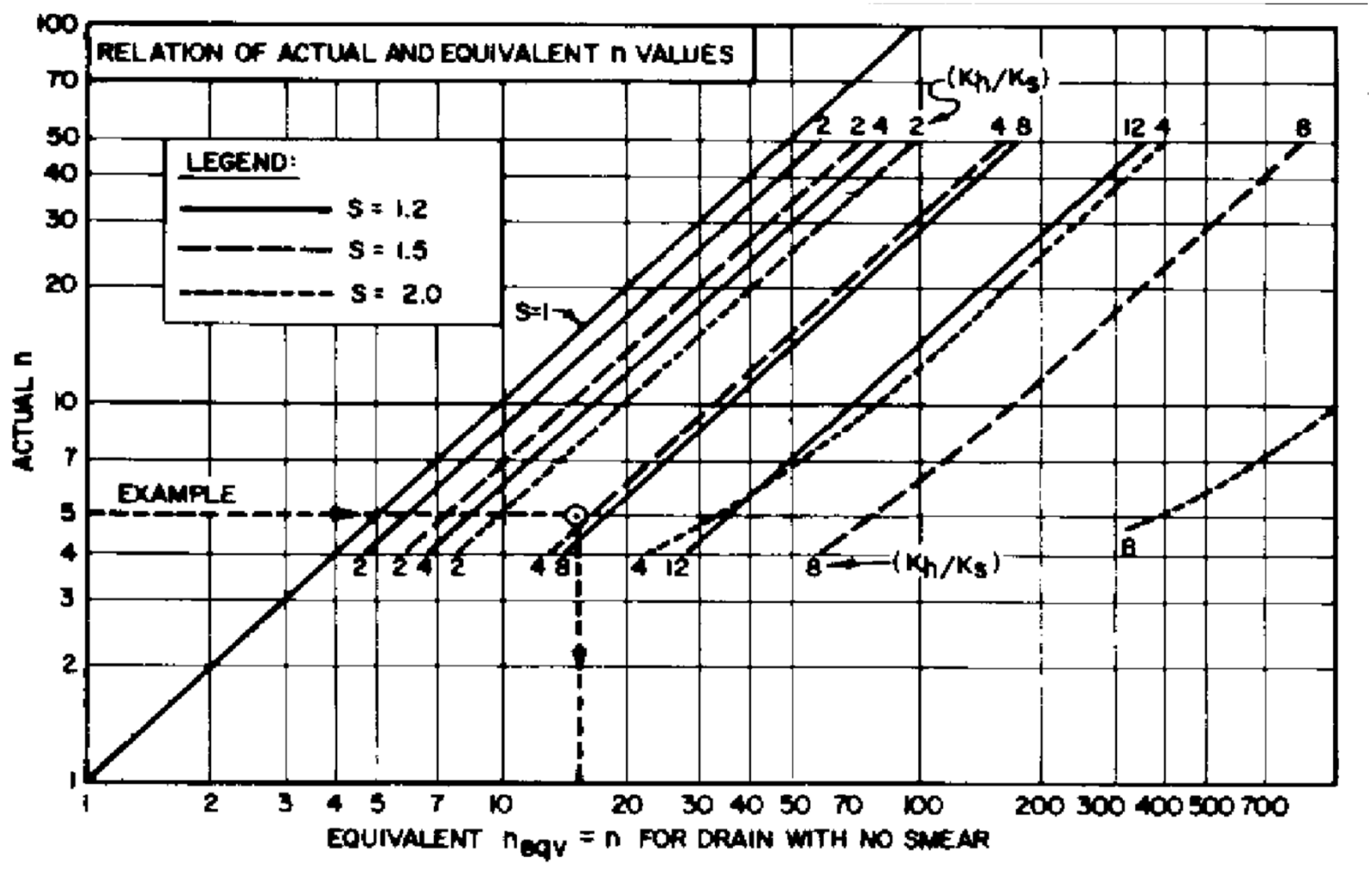
Smear effect increases with increasing drain diameter

Dynamic driving creates more disturbance than the static driving

Radial drain (vertical drain) with smear



Radial drain (vertical drain) with smear



Contoh Kasus : Perbandingan antara Prediksi dan Hasil Monitoring Penurunan PVD Treated Railway Embankment

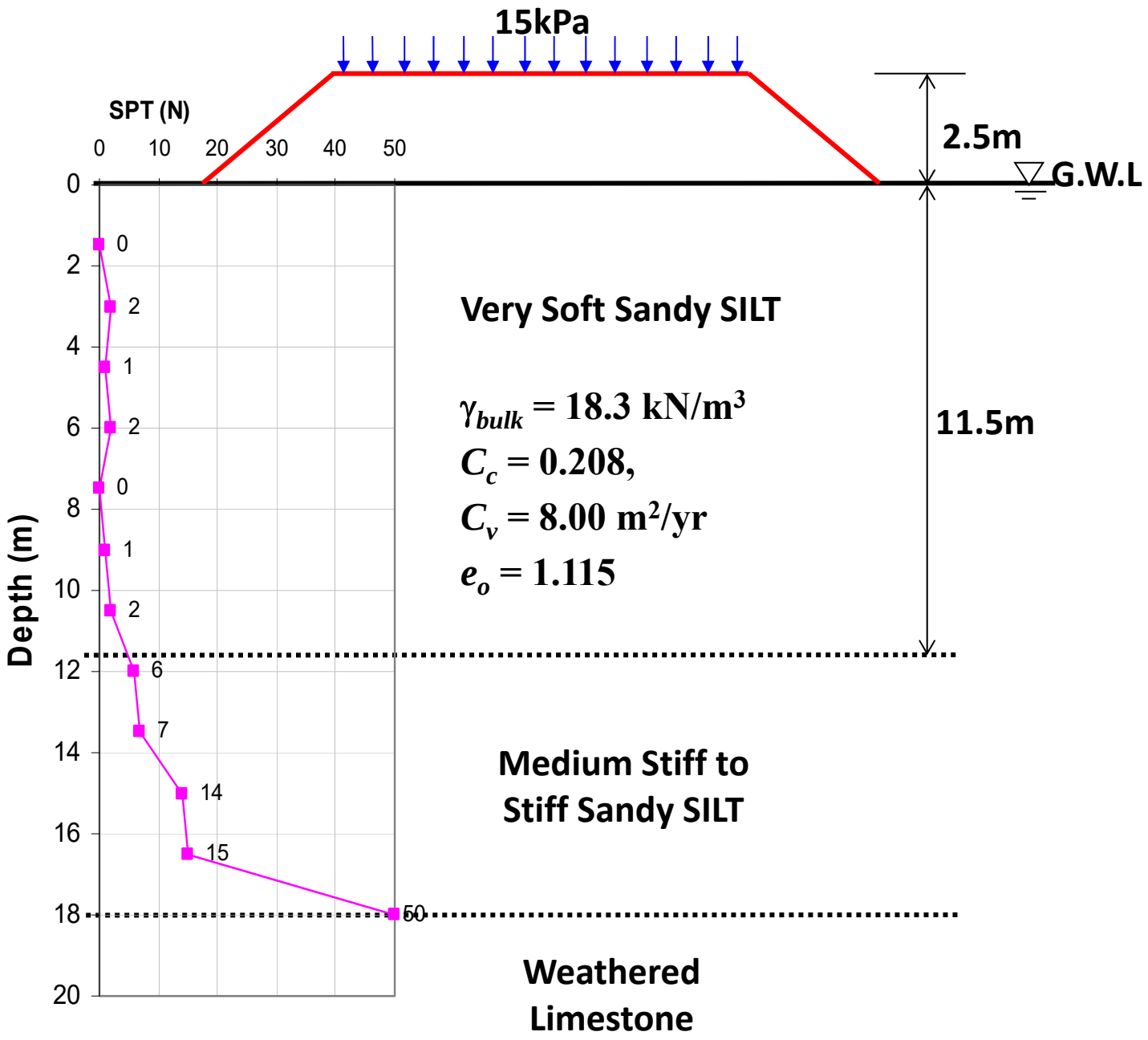
CONSTRUCTION OF RAILWAY EMBANKMENT REQUIRES STRINGENT POST CONSTRUCTION SETTLEMENT CRITERIA

SPECIFIC DESIGN CRITERIA BY KTMB :

Background and Client Requirement

1. Maximum settlement of 25mm over 6 months of commercial service
2. Maximum differential settlement of 10mm for a chord of 10m over 6 months of commercial service
3. Additional criteria for preloading/surcharging (for planning purpose) : Maximum time for any preloading/surcharging = 3 months

Soil Profile



Calculation of the Consolidation Settlement

Consolidation Settlement was calculated using the following equation (based on Terzaghi's 1-D theory) :

$$S = H.\frac{C_c}{1+e_0}.\log\left(\frac{P_o'+\Delta P'}{P_o'}\right)$$

For PVD design, the following formula was adopted to calculate % of consolidation, U_h (based on Hansbo, 1979) :

$$U_h = 1 - \exp\left(\frac{-8C_h t}{D^2 \mu}\right)$$

where:

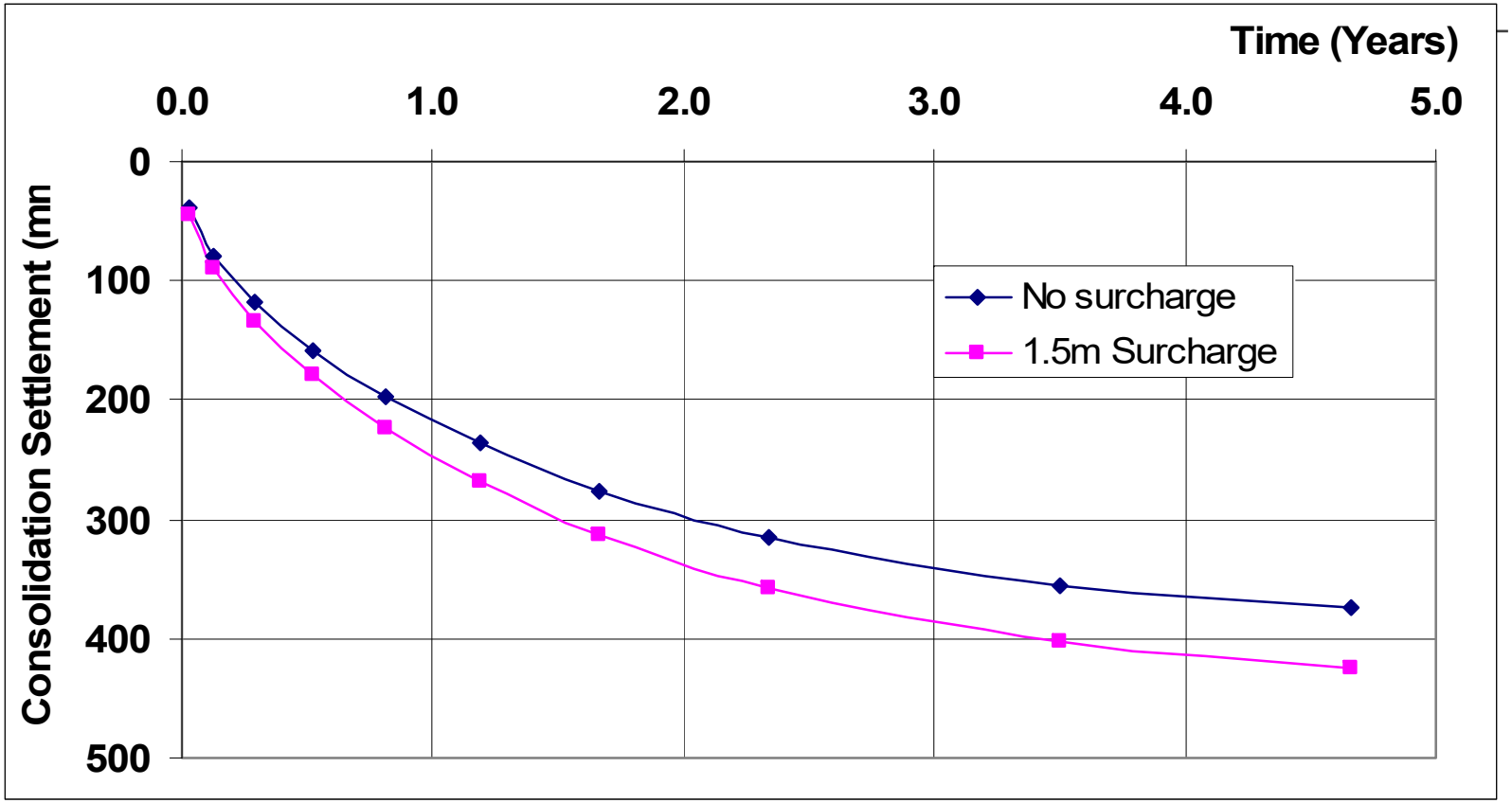
$\mu = \ln(n) - 0.75$, $n = D/d$, $d = 2(b+t)/\pi$,

D, *Dia. of dewatered cylinder* $= 1.05S$ *(triangular grid)*

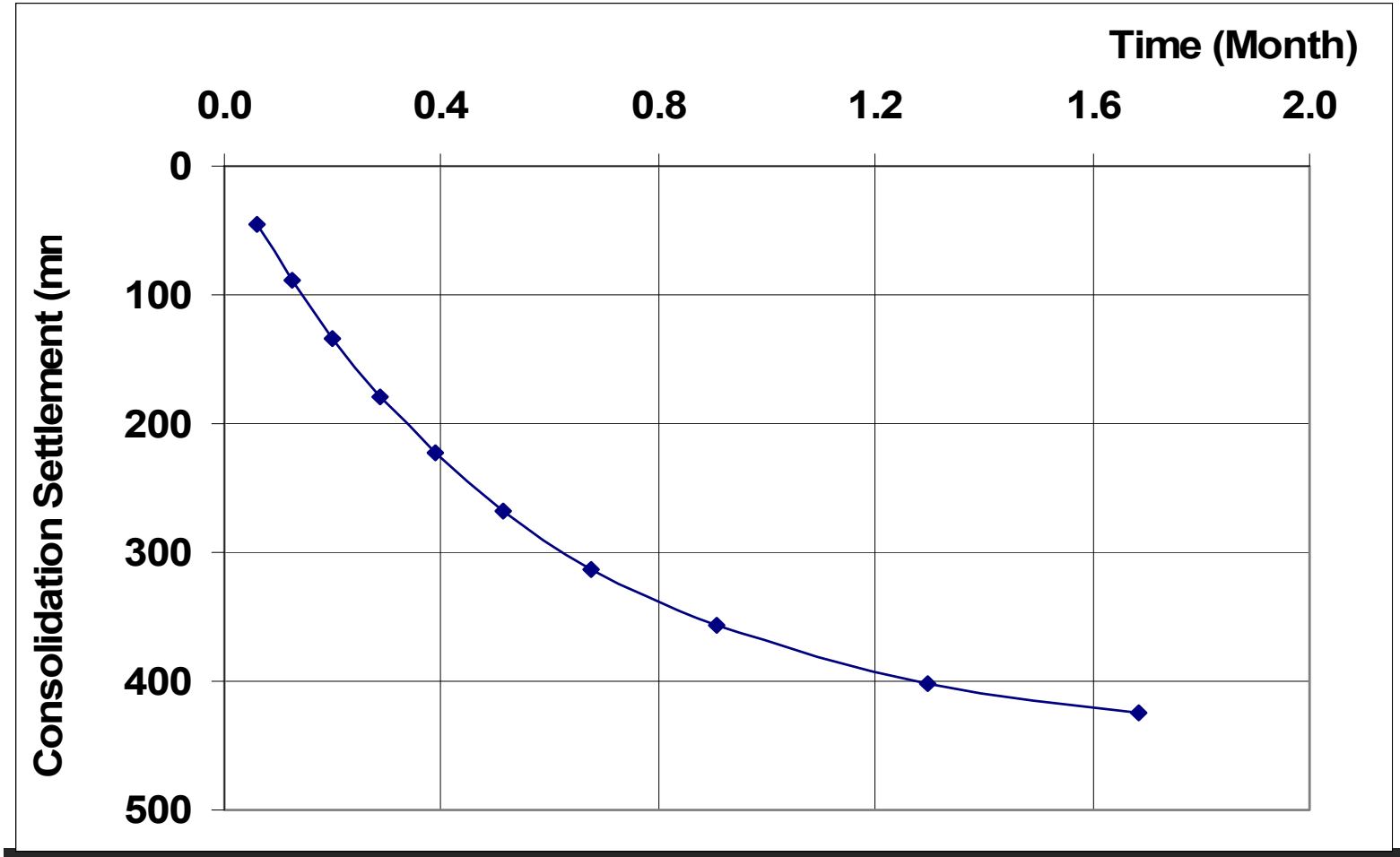
$= 1.13S$ *(square grid)*

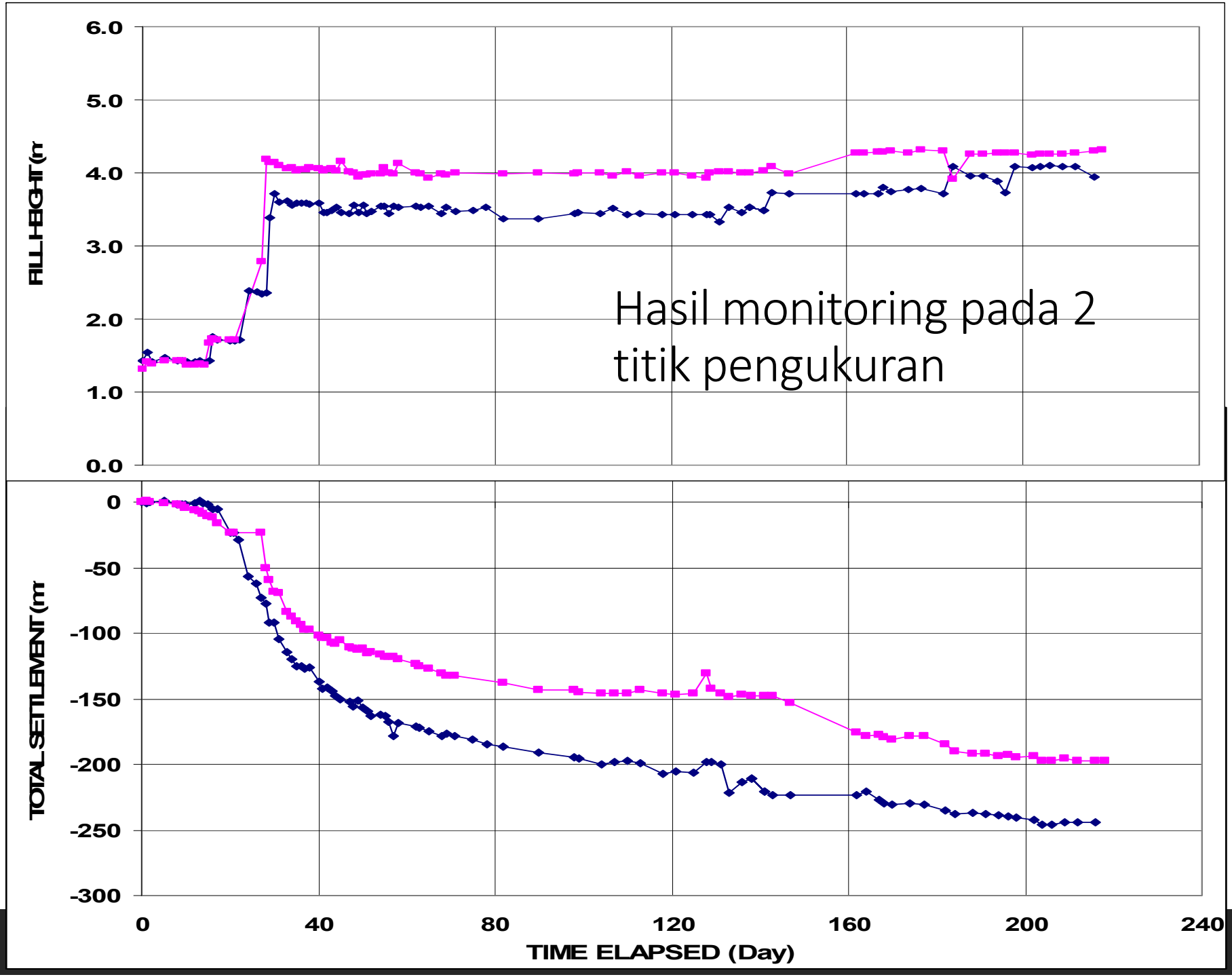
C_h = **Coeff. Of Consol. in horizontal pore water flow**

Predicted Consolidation Settlement vs Time for Embankment with/without Surcharge



Predicted Consolidation Settlement vs Time for Embankment with PVD + Surcharge




6.0
5.0
4.0
3.0
2.0
1.0
0.0
Hasil monitoring pada 2 titik pengukuran
0
-50
-100
-150
-200
-250
-300
0
40
80
120
160
200
240
TIME ELAPSED (Day)

- Comparison between the design and back-calculated settlement parameters are tabulated as below :

Parameter	$\frac{Cc}{1+e_o}$	C_h (m^2/yr)
Design	0.10	16.0
Back-calculated	0.06	9.5

- The estimated settlement was comparable to the recorded settlement. However, the rate of settlement recorded was slower than the prediction.
- Percentage of dissipation of Δu is not known due to the absence of piezometer, but can be reasonably estimated with the settlement plate record & settlement markers.


Thank you . . .
KMTC
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