SOLUTION 1

Question 1

A container of volume $2.83*10^{-3}$ m^3 weights 9.8 N. Dry sand was poured to fill the container. The container and the sand weights 52.3 N. Calculate (a) the void ratio and (b) the porosity. Assume $G_s = 2.7$.

Solution 1

$$Weight\ of\ sand\ and\ container = 52.3\ N$$

$$Weight\ of\ container = 9.8\ N$$

$$Weight\ of\ dry\ sand, W_s = 52.3 - 9.8 = 42.5\ N = 0.0425\ kN$$

$$Dry\ Unit\ Weight\ , \gamma_d = \frac{W_s}{V} = \frac{0.0425}{2.83 * 10^{-3}} = 15\ kN/m^3$$

$$\gamma_d = \frac{W_s}{V} = \frac{G_s}{1+e} * \gamma_w$$

$$Solving\ for\ e, we\ get$$

$$e = G_s * \frac{\gamma_w}{\gamma_d} - 1 = 2.7 * \frac{9.8}{15} - 1 = 0.764$$

$$Calculate\ the\ porosity$$

$$n = \frac{e}{1+e} = \frac{0.764}{1+0.764} = 0.43 = 43\ \%$$

Question 2

A fine – grained soil has a liquid limit of 300 % and a plastic limit of 55 %. The natural water content of the soil in the field is 80 % and the clay content is 60 %. Determine the plasticity index, the liquidity index, and the activity.

Solution 2

$$PI = LL - PL = 300 - 55 = 245\ \%$$

$$LI = \frac{w - PL}{PI} = \frac{80 - 55}{245} = 0.1$$

$$A = \frac{PI}{Clay\ Fraction\ (\ \%\ )} = \frac{245}{60} = 4.1$$

Question 3

The bulk density of an undisturbed soil sample was determined to be 1.96 at a water content of 14%. The void ratios in the loosest and densest states were determined to be 0.81 and 0.48, respectively. Determine the relative density of the mass. (G_S=2.7, ρ_w=1g/cm^3)

Solution 3

In the question, unit of the ρ_w was mistakenly given as kg/m^3. It is corrected here but both solutions will be accepted.

G_S=2,7 ρ_s=1,96 g/cm^3 ρ_w=1g/cm^3 e_{max}=0.81 e_{min}=0.48

$$\rho_s = \frac{G_s * (1 + w)}{1 + e} * \rho_w$$

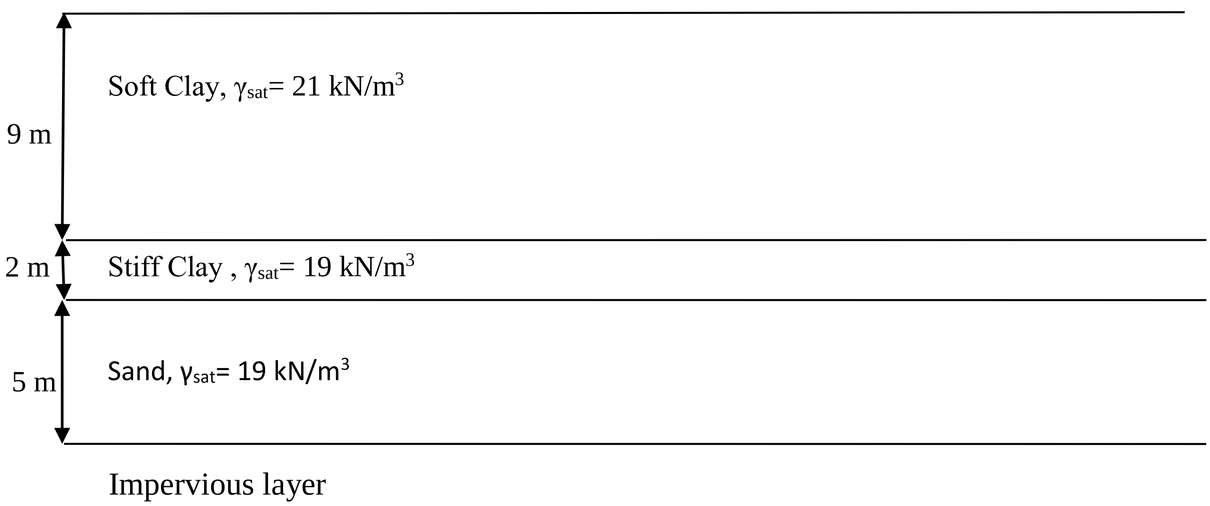
$$1.96 = \frac{2.7 * (1 + 0.14)}{1 + e} * 1$$

$$e = 0.57$$

$$D_R = \frac{e_{max} - e}{e_{max} - e_{min}} * 100 = \frac{0.81 - 0.57}{0.81 - 0.48} * 100 = 72\ \%$$

Question 4

The soil profile for the construction site consists of 9 m soft clay followed by 2 m of another stiff clay and 5 m of sand. The ground water level is at the ground surface and the piezometric head for the sand was 3 m above the top of the ground water level. If an excavation of 7 meter is planned, determine the level to which the artesian water should be lowered in order to prevent the heave of the bottom of the excavation.



Solution 4

Weight of the soil above = 2 x 21 + 2 x 19 = 80 kN/m^2

Uplift pressure = 14 x 10 = 140 kN/m^2

To prevent the bottom heave uplift pressure should be lowered to 80 kN/m^2.

(140 – 80)/10 = 60/10 = 6 m

The artesian water level should be lowered 6 m (or 3 m below the ground surface).

Question 5

Material for an earth fill was available from three different borrow sites. In the compacted state volume of the fill measured as 100,000 m^3 at a void ratio of 0.70. The corresponding in-situ void ratio and cost (material and transportation) of the material for the three sites is as follows:

Borrow Sites	**Void Ratio**	**Total Cost per Cubic Meter**
1	0.8	TL 6.40
2	1.7	TL 6.00
3	1.2	TL 5.15

Determine the most economical sites.

Solution 5

Project site:

$$V_V + V_S = 0.7 * V_S + V_S = 100{,}000\ m^3$$

$$V_S = \frac{100000}{1.7} = 58{,}823.53\ m3$$

Borrow site 1:

$$V_1 = V_S * (1 + e_1) = 58823.53 * (1 + 0.8) = 105882.3\ m^3$$

$Total\ cost =$ Total Cost per Cubic Meter * V_1= 6.4 * 105882.3 = 677,647.06 TL

Borrow site 2:

$$V_2 = V_S * (1 + e_2) = 58823.53 * (1 + 1.7) = 158823.5\ m^3$$

$Total\ cost =$ Total Cost per Cubic Meter * V_2= 6 * 158823.5 = 952,941.18 TL

Borrow site 3:

$$V_3 = V_S * (1 + e_3) = 58823.53 * (1 + 1.2) = 129411.7\ m^3$$

$Total\ cost =$ Total Cost per Cubic Meter * V_3= 5.15 * 129411.7 = 666,470.59 TL

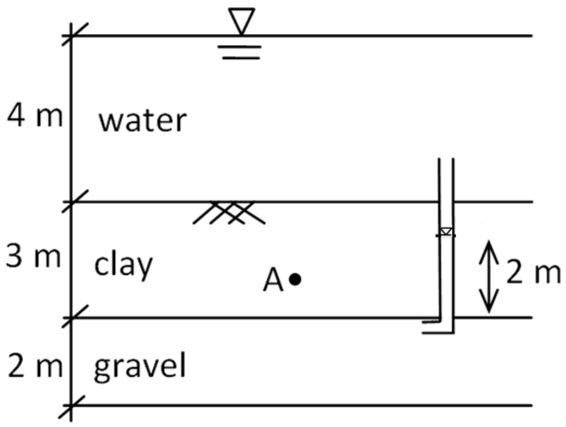
Borrow Sites	**Total Cost**
1	677,647.06 TL
2	952,941.18 TL
3	666,470.59 TL

According to the results, borrow sites 3 is the most economical sites.

Question 6

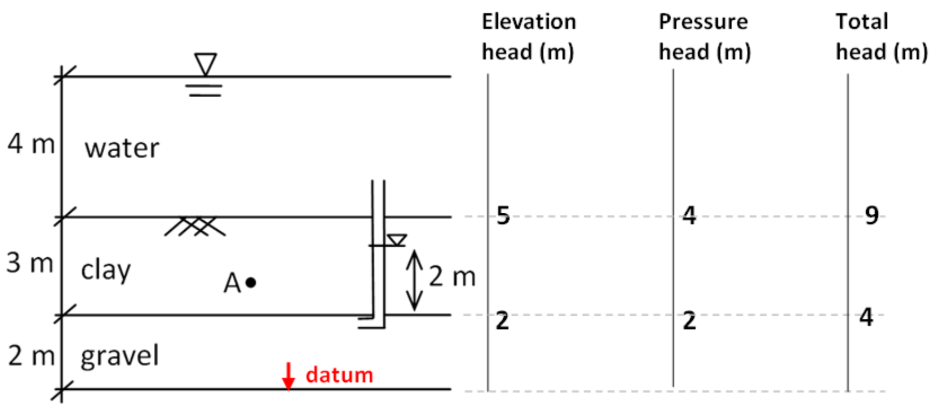
There is a free standing water in a pond. Underneath the pond a 3-m-thick clay layer exists. For the soil profile given below, assume 1D steady state flow is taking place.

a) Calculate hydraulic gradient in clay layer.
b) If the rate of flow through the clay layer is observed to be 0.5 m^3/year for 1 m^2 cross sectional area perpendicular to flow direction, what is the coefficient of permeability of the clay layer, in cm/sec?
c) Calculate where the water would rise in the tube inserted at the mid-depth of the clay? Indicate on the figure.
d) Calculate effective stress at point A, located 1 m above the boundary between clay and gravel, using two methods i) Total stress and pore pressure method, ii) Buoyant unit weight and seepage force method. Saturated unit weight of clay is 19 kN/m^3.



Solution 6

Select datum at the base of the gravel layer.



a) Calculate hydraulic gradient in clay layer. We consider two points, where it is easy to calculate total head: for example, a point located at the top, and another point located at the bottom of clay layer, and consider total head at these points.

$$i = \Delta H / L = (9 - 4) / 3 = 1.67$$

b) If the rate of flow through the clay layer is observed to be 0.5 m^3/year for 1 m^2 cross sectional area perpendicular to flow direction, what is the coefficient of permeability of the clay layer?

$q = A \cdot k \cdot i$

$0.5\ m^3/\text{year} = 1\ m^2 \cdot k \cdot (1.67)$

$k = 9.5\times10^{-7}$ cm/sec

c) Calculate where the water would rise in the tube inserted at the mid-depth of the clay. Indicate on the figure.

Find pressure head at mid-depth of clay.

Note: Total head varies linearly in a given soil, (or hydraulic gradient is constant in a given soil in 1D flow.)

Therefore total head at the mid-depth of clay is 6.5 m.

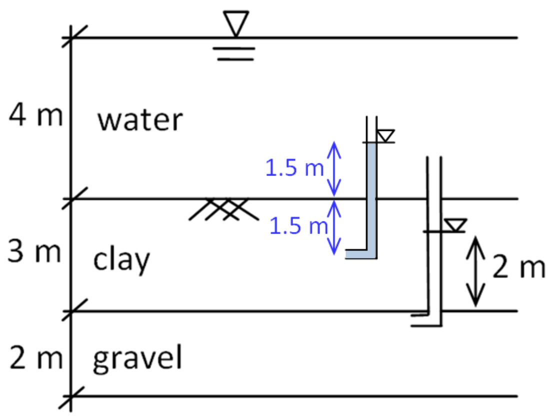
Elevation head at the mid-depth of clay, according to the given datum is 3.5 m.

Therefore pressure head at the mid-depth of clay is 3 m.

OR: Alternative way:

Pore pressure changes linearly in the clay layer. At the top of the clay it is 40 kPa (pressure head×unit weight of water), and it is 20 kPa at the bottom of the clay. Therefore at the mid-depth of clay it must be 30 kPa, which means 3 m of pressure head.

Therefore, water level in a tube inserted at that point would be at 1.5 m above the top of the clay layer.



d) Calculate effective stress at point A, located 1 m above the boundary between clay and gravel, using two methods i) Total stress and pore pressure method, ii) Buoyant unit weight and seepage force method. Saturated unit weight of clay is 19 kN/m^3.

i) Using total stress and pore pressure method:

Total stress at point A: $\sigma = 4\times10 + 2\times19 = 78$ kPa
Pore pressure at point A: $u = 26.7$ kPa
(26.7 kPa is obtained by linearly interpolating between pore pressure values of 40 and 20 kPa at the top and bottom of the clay, respectively)

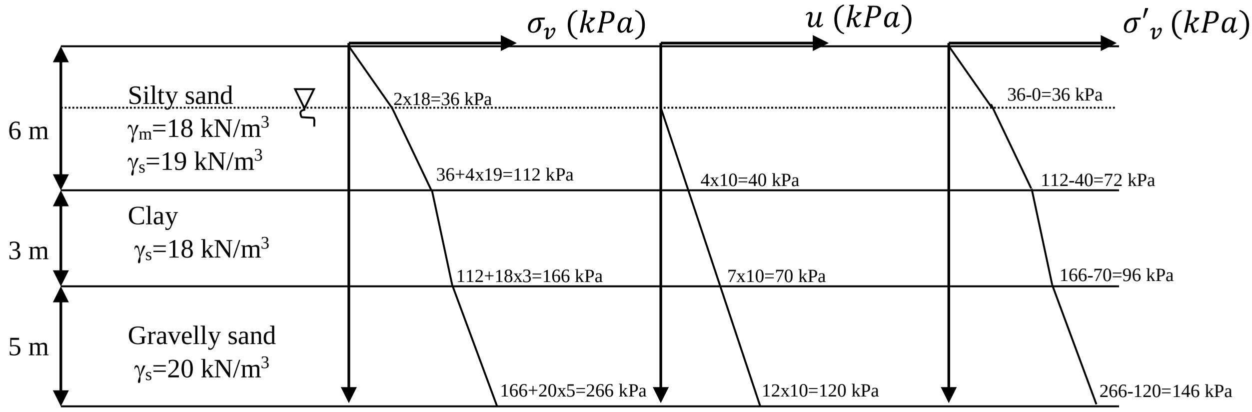
Effective stress at point A: $\sigma' = 78 - 26.7 = 51.3$ kPa

ii) Using buoyant unit weight and seepage force method:

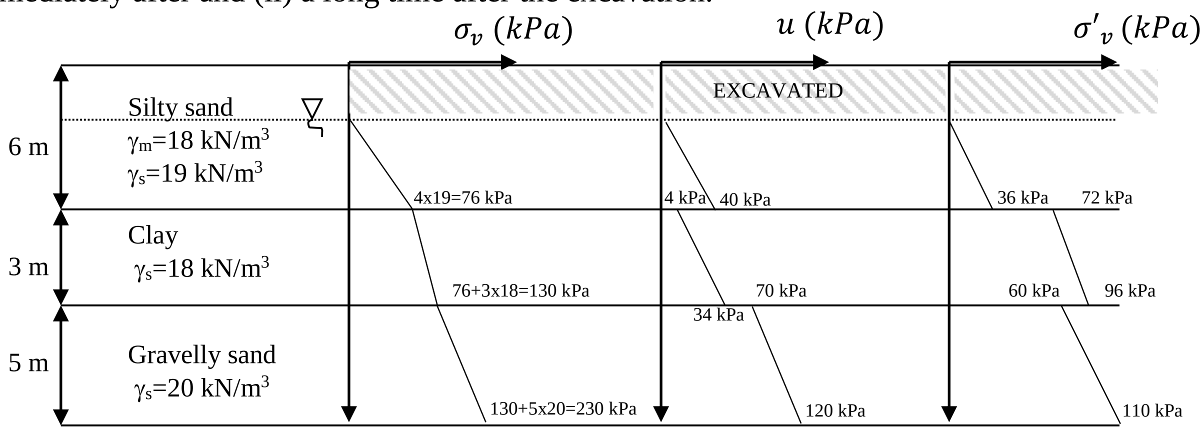
$\sigma' = z\,(\gamma' \pm i\,\gamma_w)$
$\sigma' = 2\,[\,(19\text{-}10) + 1.67\,(10)\,] = 51.3$ kPa

Question and Solution 7

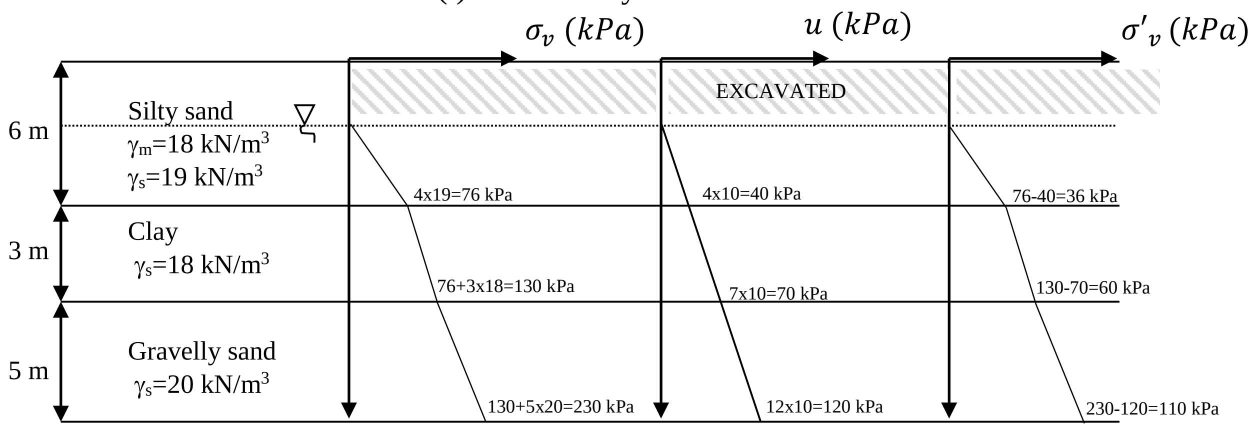
(a) As shown in the figure given below, a 6 m thick layer of silty sand overlies a clay layer of 3 m in thickness. Below this clay layer there lies a 5 m thick gravelly sand layer underlain by bedrock. The ground water table is at 2 m depth below the ground surface. Draw the total stress, pore pressure and effective stress diagrams. (Note: γ_m, γ_s are the moist and saturated unit weights and should be used for the soil layers above and below water table, respectively)



(b)Up to ground water table, 2 meter of the silty sand layer is excavated for future construction purposes. Draw the total stress, pore pressure and effective stress diagrams (i) immediately after and (ii) a long time after the excavation.



(i) Immediately after



(ii) Long time after

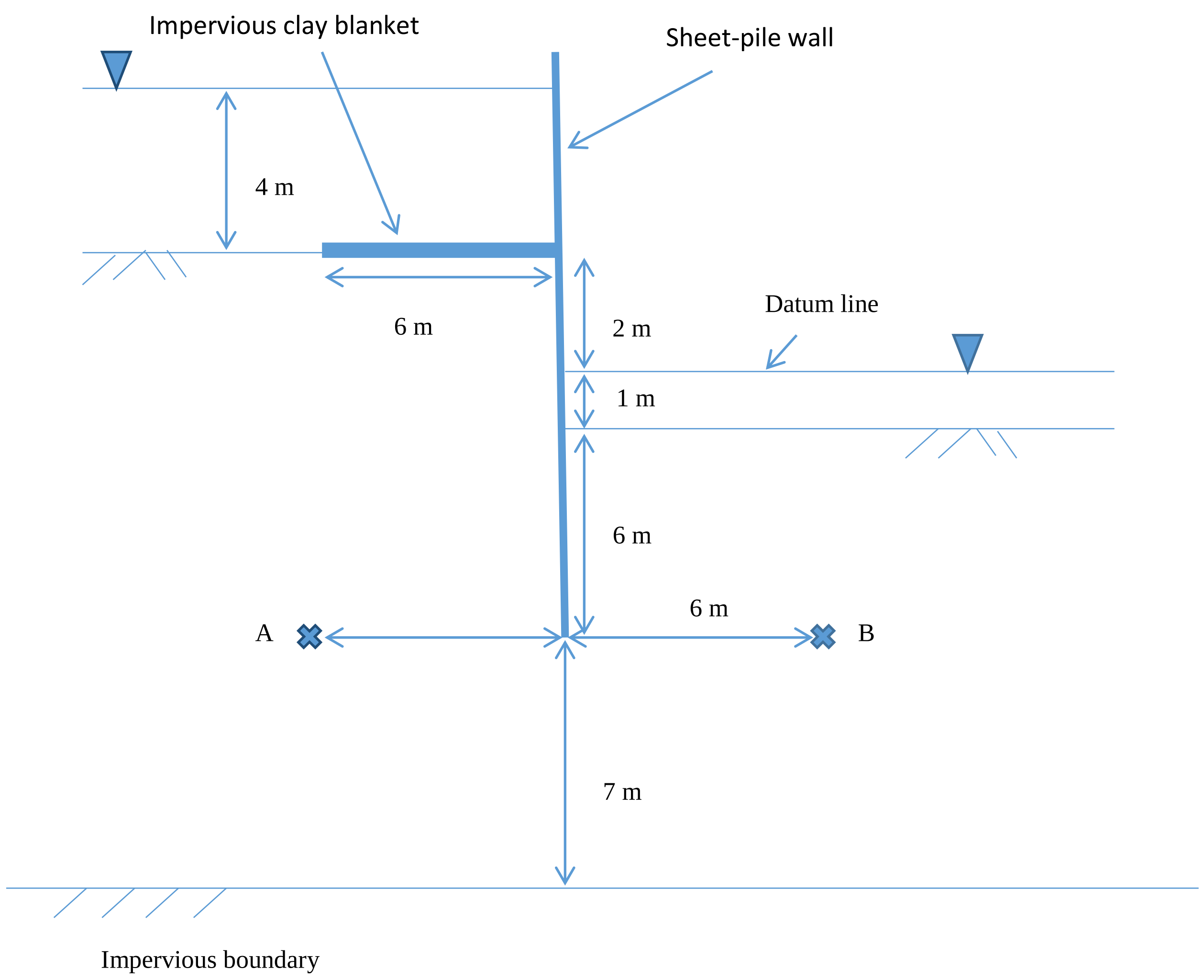
Question 8

Section of a sheet-pile water retaining structure is shown below (not to scale). The soil, which is silty sand, has a saturated unit weight of γ_{sat} = 21 kN/m^3 (use γ_{water} = 10 kN/m^3).

a) Draw the section to scale using 1 cm: 2 m, and draw a flow net for the two-dimensional seepage problem.
b) Calculate the total amount of water seeping beneath the structure if the coefficient of permeability of the soil is 1.5 * 10^{-4} cm/s and the length of the structure is 40 m.
c) Determine the total head at point A.
d) Determine the pore pressure at point A.
e) Calculate the effective stress at point B using
   i) Total saturated weight and resultant boundary water force approach

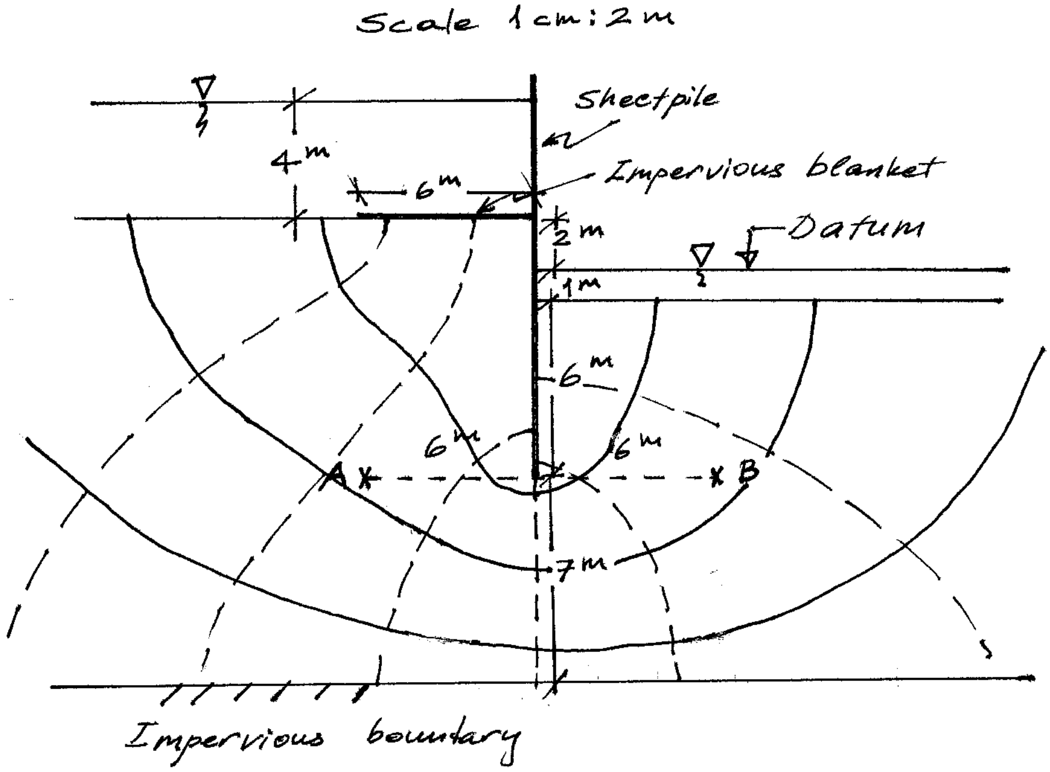
   ii) Effective (buoyant) weight and seepage force approach (assume 1D flow at point B).

f) Determine the factor of safety against sand boiling (or quick sand condition) on the downstream side of the sheet-pile structure.



Solution 8

a) Drawing of the section using 1 cm: 2 m is as follows:



b) $k = 1.5*10^{-4}$ cm/s = $1.5*10^{-6}$ m/s

$N_f = 3.4$, $N_d = 7$ m, $H = 6$ m

$q = k\,H\,N_f / N_d$

$q = 1.5*10^{-6} * 6 * 3.4 / 7 = 4.37*10^{-6}\ m^3/s/m$

$q = 4.37*10^{-6}\ (24 * 60 * 60)\ 40 = 15.11\ m^3/day$

c) $h_A = h_C + N_{C-A}\,(H/N_d)$ (assume point C is on the downstream side soil surface)

$h_C = z_C + u_C/\gamma_W$

$h_C = -1 + 1 = 0$

$h_A = 0 + 4.7\ (6/7) = 4.03$ m

d) $h_A = za + u_A/\gamma_W$

$4.03 = -7 + u_A/\gamma_W$

$u_A = 110.3$ kPa

e) Effective stress at point B

i. Using total wt. & boundary water force method

Total head at point B = 0 + 1.3 * 6/7 = 1.11 m

$H_B = z_B + u_B/\gamma_W$ therefore $1.11 = (-7) + u_B/\gamma_W$

u_B=81.1 kPa

$\sigma' = (6 * 21 + 1 * 10) - 81.1 = 54.8$ kPa

ii. Using effective wt. & seepage force method

Hydraulic gradient: $i = (1.3 * 6/7) / 6 = 0.186$

$\sigma' = 6 (21 - 10) - 0.186 * 10 * 6 = 54.8$ kPa

f) Consider 6 m deep and 3 m wide section of soil in front of the sheetpile on the downstream side. Average equipotential drop in this section is 2.

$i = (2*6/7) / 6 = 0.286$

$i_{cr} = (\gamma_{sat} - \gamma_{water}) / \gamma_{water}$

$i_{cr} = (21 - 10) / 10 = 1.1$

$FS = i_{cr} / i = 1.1 / 0.286 = 3.85$