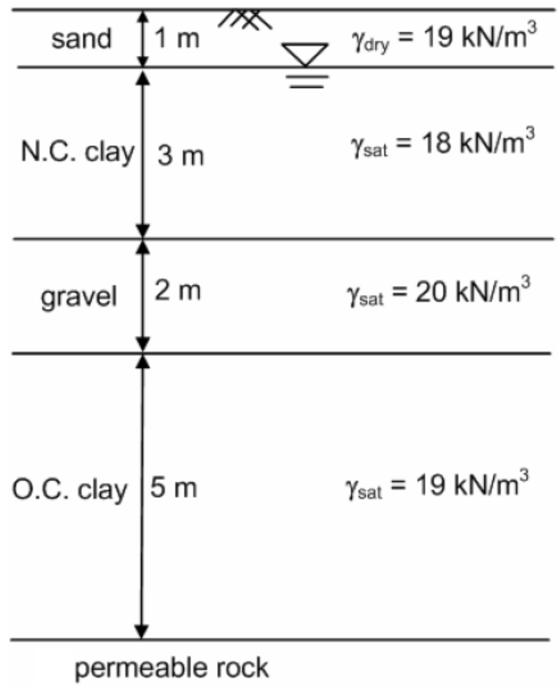
HOMEWORK 4 – SOLUTION

1) <u>At the mid-depth of N.C. Clay</u>
(at 2.5 m below ground surface):



Before the fill is placed:
$\sigma = 1 \times 19 + 1.5 \times 18 = 46$ kPa
$u = 1.5 \times 10 = 15$ kPa
$\sigma' = \sigma - u = 46 – 15 = 31$ kPa

Immediately after the fill is placed:
$\sigma = 46 + 4 \times 17 = 114$ kPa
$u = 1.5 \times 10 + 4 \times 17 = 83$ kPa
$\sigma' = \sigma - u = 114 – 83 = 31$ kPa
OR
σ' remains the same (31 kPa)
$u = 114-31 = 83$kPa

After the clay is consolidated:
$\sigma = 46 + 4 \times 17 = 114$ kPa
$u = 15$ kPa
$\sigma' = \sigma - u = 114 – 15 = 99$ kPa

<u>At the mid-depth of O.C. Clay</u>
(at 8.5 m below ground surface):

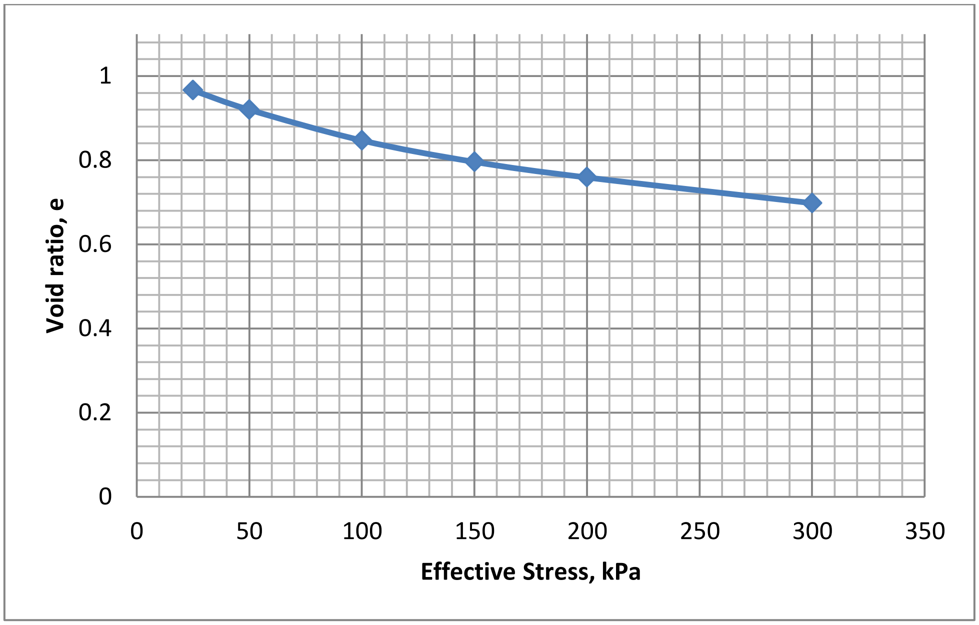
Before the fill is placed:
$\sigma = 1 \times 19 + 3 \times 18 + 2 \times 20 + 2.5 \times 19 = 160.5$ kPa
$u = 7.5 \times 10 = 75$ kPa
$\sigma' = \sigma - u = 160.5 – 75 = 85.5$ kPa

Immediately after the fill is placed:
$\sigma = 160.5 + 4 \times 17 = 228.5$ kPa
$u = 7.5 \times 10 + 4 \times 17 = 143$ kPa
$\sigma' = \sigma - u = 228.5 – 143 = 85.5$ kPa

After the clay is consolidated:
$\sigma = 160.5 + 4 \times 17 = 228.5$ kPa
$u = 75$ kPa
$\sigma' = \sigma - u = 228.5 – 75 = 153.5$ kPa

2) From question 1, σ_0'= 31 kPa and σ_f'= 99 kPa. By linear interpolation, from the given data, void ratio values corresponding to effective stress values can be found:

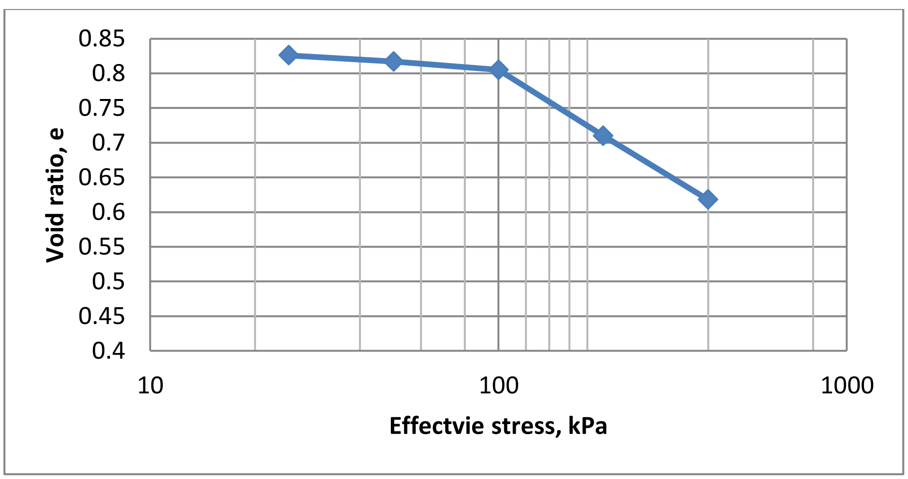
(e_0, σ_0') = (0.9549, 31) and (e_f, σ_f') = (0.8485,99)



Using these values, m_v can be calculated for the effective stress range of 31 to 115 kPa:

$$m_v = \frac{\Delta e}{\Delta \sigma\prime} \cdot \frac{1}{1+e_0} = \frac{(0.9549-0.8485)}{(99-31)} \cdot \frac{1}{1+0.9549} = 8\ x\ 10^{-4}\ \mathrm{m^2/kN}$$

3) Plotting the given data:



From the plot, σ_p'= 100 kPa

Using two effective stress values, that are on the linear portion of the curve before the preconsolidation pressure, for example 25 and 50 kPa:

$$C_r = \frac{\Delta e}{\Delta \log\sigma'} = \frac{(0.826 - 0.817)}{\log 50 - \log 25} = 0.02989$$

Using two effective stress values, that are on the linear portion of the curve after the preconsolidation pressure, for example 200 and 400 kPa:

$$C_c = \frac{\Delta e}{\Delta \log\sigma'} = \frac{(0.710 - 0.618)}{\log 400 - \log 200} = 0.30562$$

σ_v' = 1x 19 + 3 x 18 + 2 x 20 – 5 x 10 = 63 kPa

OCR = σ_p' / σ_v' = 100/63 = 1.59

4) <u>N.C. clay layer:</u>
   (e_0, σ_0') = (0.9549, 31) and σ_1' = 99 kPa, $\Delta\sigma$'= 4 x 17 = 68 kPa

   $S_{N.C.clay}$ = m_v x H x $\Delta\sigma$' = $8\ x\ 10^{-4}\ x\ 3\ x\ 68 = 0.1632\ m$

   <u>O.C. clay layer:</u>
   σ_0' = 85.5 kPa and σ_1' = 153.5 kPa. To find the initial void ratio at σ_0' = 85.5 kPa, we can use the lab data and linear interpolating between the void ratios corresponding to 50 and 100 kPa:
   e_0 = 0.8085

   Since the effective stress after consolidation is (153.5) kPa greater than the preconsolidation pressure (100 kPa), we should use the equation with C_r and C_c.

   $S = \frac{C_r}{1+e_0}.H.\log\left(\frac{\sigma_p'}{\sigma_0'}\right) + \frac{C_c}{1+e_0}.H.\log\left(\frac{\sigma_1'}{\sigma_p'}\right) = \frac{0.02989}{1+0.8085}.5.\log\left(\frac{100}{85.5}\right) + \frac{0.30562}{1+0.8085}.5.\log\left(\frac{153.5}{100}\right) =$ 0.1628 m

   (Note: it is just a coincidence that both N.C. and O.C. clays gave very similar settlement values.)

5) 7 months after the end of a 2-month construction period is same as 7+2/2 = 8 months after instantaneous loading.

   Calculating the average degree of consolidation of each clay layer at 8 months:

   <u>At 8 months, N.C. clay:</u>

   $T_v = \frac{c_v\ x\ t}{d^2} = \frac{1.8\ x\ (8/12)}{(1.5)^2} = 0.533$ $\Rightarrow$ lower graph $\Rightarrow$ U_{av} = 78 %

$S_{8months} = S_{final} \times U_{av} = 0.78 \times 0.1632 = 0.127$ m

<u>At 8 months, O.C. clay:</u>

$T_v = \frac{c_v \ x \ t}{H_d^2} = \frac{1.2 \ x \ (8/12)}{(2.5)^2} = 0.128 \quad \Rightarrow \quad$ lower graph $\quad \Rightarrow \quad U_{av} = 40\ \%$

$S_{8months} = S_{final} \times U_{av} = 0.40 \times 0.1628 = 0.0652$ m

<u>Ground surface settlement at 8 months:</u>

0.127 + 0.0652 = 0.16 m

6) $S_t = S_{final} \times U_{av} \quad \Rightarrow \quad 0.05\text{m} = 0.1628 \times U_{av} \quad \Rightarrow \quad U_{av} = 30.7\%$.

From lower graph, Tv = 0.07

$$T_v = \frac{c_v \times t}{d^2} \qquad 0.07 = \frac{(1.8)\times(t)}{(1.5)^2} \qquad t = 0.0875 \text{ years} \approx t_c/2 = 1 \text{ month}$$

Note that the time calculated here is from the middle of the construction period, placing the answer to the end of construction period.

7) For O.C. clay layer at 1 year after the end of construction (12+2/2 = 13 months after an equivalent instantaneous loading):

$$T_v = \frac{c_v \times t}{H_d^{\ 2}} = \frac{1.2 \times (13/12)}{2.5^2} = 0.208$$

Using the upper graph, for Tv = 0.208 and z/H_d = 4 m / 2.5 m = 1.6, the degree of consolidation at that point at that time is about $U_z = 0.57$.

$\Rightarrow$ 57% of $\Delta\sigma$ has been transferred to σ' $\Rightarrow$ 43% of $\Delta\sigma$ is still on u

$\Rightarrow u = u_o + \Delta u = 9 \times 10 + 0.43 \times 68 = 90 + 29.24 = 119.24$ kPa